Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/chemicalengineer13newy

Metallurgical & Chemical Engineering

Being the Incorporation of
Electrochemical and Metallurgical Industry
and Iron and Steel Magazine

Published Monthly to August, 1915,
Semi-monthly Since September 1, 1915.

Volume XIII

From January to December, 1915

436838
3. 7. 45

NEW YORK:
McGRAW PUBLISHING COMPANY, Inc.

INDEX TO VOLUME XIII

GENERAL ALPHABETICAL INDEX

Entries from the Synopsis of Periodical Literature are indicated by S. (Synopsis); from the Analysis of Current Electrochemical, Chemical and Metallurgical United States Patents by P. (Patents); from the Digest of Electrochemical United States Patents Prior to July, 1902, by D. (Digest).

A

ABBE Engineering Co. ... 691
Abbe, Paul O. ... 745, 918
Abrasive Material Co. ... 860
Abrasives, for grinding steel. Kalmus. (P.) ... 762
Accident prevention in the chemical industries. Keough ... 731
Acetone from hardwood distillations ... 30
ACID:
——At close of 1915 ... 710
——Hydrochloric. Electrolysis ... 964
——Nitric. Electrolysis ... 964
——Orthophosphoric ... 964
——Sulphuric. Concentration. Mason ... 17
—— Concentration in silica dishes. Marshall ... 136
—— Contact process. Brockbank. (P.) ... 971
—— Electrolysis ... 964
—— Erecting plants ... 846
—— New agricultural use for ... 648
Acid process for electric steel. Müller. (S.) ... 640
Acid-resisting alloy. Parr ... 712
Acid treatment of gold precipitate. (S.) 118
Actinometer. Kershaw ... 970
Addicks, Lawrence (Photo) ... 315, 708
Advice to consulting metallurgists. Blythe 442
Aeration treatment of sewage. Bartow ... 901
AGITATOR:
——Dorr in series ... 13
——Dorr ... 91
——Dorr. (P.) ... 392
——For slime pulps. Vandercook (P.) ... 924
——Trent, At West End mill. Carpenter. 671
Agriculture, New use for sulphuric acid 648
Ainsworth & Sons, Wm. G. ... 745
Air compressor, Continuous running. Nash ... 460
Air-gun for repairing furnaces ... 416, 529, 582
Air-lift pumping. Sullivan Machinery Co. ... 392
——Berggreen (S.) ... 507
Alarm, Bottle-filling. Hall ... 347
Alaska Gastineau Mill ... 273
Alaska Gold Mines Co. ... 16
Alaskan Railroad of the Government ... 271
Albumin, Coagulation by electrolytes. Bancroft ... 317
Alcohol, Rewards for methods of utilizing ... 352
Alcohol from hardwood distillation. French and Withrow ... 30
Alkalies, Electric furnace manufacture of. Acker (P.) ... 764
Alkalies, Situation at close of 1915 ... 710
Allis-Chalmers Co ... 860
Allotropy of metals. Vosmaer ... 535
ALLOYS:
——Acid-resisting. Parr ... 721, 973
——Alloy steels. Norris ... 739
——Aluminium. McAdams (P.) ... 504, 570
——Aluminium, Bronze. Corse ... 712
——Copper, Titanium, Magnesium. Vickers (P.) ... 701
——Iron alloy for dynamo-electric purposes. Rühel (P.) ... 249
——Iron, Cobalt, Chromium. Hayes (P.) 701
——Nickel, Copper, Lead ... 644
——Patents relating to electroplating, 196, 268
——Platinum and Osmium. Zimmerman (P.) ... 762
——Pyrophoric alloy suit ... 145
——Rapid analysis of bearing metals and high-copper content alloy. Lutts 347, 370
——Silver and cadmium ... 378
——Ulcoloy, A new copper-lead alloy ... 378
——Zirconium, Iron for lamp filaments Brown (P.) ... 924

ALLOYS: (Continued.)
All-sliming cyanide plants in California. Palmer ... 617
Alum for water purification. Hoover (S.) 508
Alumina in steel. Comstock ... 891
——Fitz Gerald ... 936
ALUMINIUM:
——Alloy. McAdams (P.) ... 504
——Alloy (P.) ... 570
——Autogenous welding. Pannell ... 712
——Bronze alloys. Corse ... 712
——Chloride process for refining high boiling petroleum oils. McAfee. 592
——Coating on different metals (colorizing). Ruder ... 325
——Consumption in 1914 ... 546
——Die casting. Pack ... 712
——Effect of enhanced value on silver ... 526
——Furnace for producing alumina. Schwan (P.) ... 569
——Melting aluminium chips. Gillett ... 712
——Nitride manufacture. Bunet (P.) ... 504
——Nitride-Askenasy ... 966
——Plating, Patents relating to (D.) ... 341
——Plating On. Hall (P.) ... 570
——Price changes ... 706
——Southern Aluminium Co.'s plant ... 832
——Statistics ... 710
——Treatment of surfaces for plating. Roux (P.) ... 570
Alumino, Vanadium. Clark ... 712
Alunite deposits being developed in Utah. (See also Potash), 482, 526, 582
Amalgamation. Relative Efficiency of various amalgams. Thomson, Keffer ... 367
Amalgamation tailings. Determination of mercury ... 896
Amalgamation tests. Sharwood (S.) ... 927
Amendment of the Patent Laws ... 76
America. Electrochemistry in ... 1
American Bitumastic Enamels Co ... 691
American Blower Co. ... 717, 918
American Chemical Society, 210, 351, 419, 494, 782
——New York Section ... 244
——New Orleans Meeting ... 280
——Southern California Section ... 530
——Seattle Meeting ... 587
——National Exposition ... 691
——New York Section ... 710
——University and Industry ... 885, 941
American Cyananid Co. ... 213
American Electrochemical Society in its external relations. (Pres. address.) Lidbury ... 277
American Electrochemical Society, 185, 210, 351, 419, 494, 782
——New York Section ... 211, 241, 884
——Niagara Falls Section ... 651, 776
——Atlantic City Meeting ... 314
——San Francisco Meeting ... 654
——Exposition of Chemical Industries, 691, 697, 700
American Electroplaters' Society ... 176
American Foundrymen's Association Convention, Atlantic City ... 712
American Hard Rubber Co. ... 691
American Institute of Chemical Engineers, 351, 418, 710
——Philadelphia meeting ... 41
——Los Angeles meeting ... 530
——San Francisco meeting ... 603
——Exposition of chemical industries, 691, 699
American Institute of Metals, Atlantic City meeting ... 712
American Institute of Mining Engineers, 98, 177, 208, 419, 887
——Montana Section ... 196
——San Francisco Meeting ... 654
——Columbia Section ... 904

American Iron and Steel Institute:
——Corrosion problem ... 420
——Cleveland meeting ... 830
American Mining Congress:
——Resolutions ... 42
——San Francisco ... 652
American Ore Flotation Co. ... 348
American Paper and Pulp Association, 520, 691, 700
American Potash Co. ... 860
American Shop Equipment Co. ... 586
American Smelting & Refining Co. ... 274
American Transformer Co. ... 691
American Vulcanized Fibre Co. ... 746
American Window Glass Co. ... 800
American Zinc, Lead and Smelting Co. ... 275
Ammonia, Lymn ammonia and producer-gas plant ... 456
Ammonium sulphate production in 1914 (S.) ... 638
Amorphous solids. Chemistry. Lewis ... 921
Ampco bronze ... 931
Ampere-hour meter for electrolytic works ... 191
Anaconda Copper Co. ... 207, 403, 526, 557
Anaconda, Powdered coal plant ... 333
Anaconda Copper Co., Powdered coal practice. Mathewson ... 728
ANALYSIS:
——Analoid method for phosphorus determination. (S.) ... 191
——Bearing metals and high copper content alloys. Lutts ... 346
——Brazilian monazite sand ... 403
——Carbon determination with platinum boats. Siever ... 525
——Carbon determination by the combustion method. Rich ... 347
——Carbon combustion apparatus. Cox (P.) ... 504
——Carbon and oxygen in steel and tungsten powder. Electric furnace. Johnson ... 17
——Chromium and vanadium in steel. Rich and Whittam ... 238
——Electro-analysis. Smith ... 327
——Determination of antimony, arsenic, bismuth, cadmium, copper, lead, silver, tin, by electrolysis. Schoch (S.) ... 568
——Estimation of aromatic hydro-carbons in cracked petroleum. Rittman, Twomey, Egloff ... 682
——Gold and silver in cyanide solutions. Bahney (S.) ... 252
——Gold-bearing cyanide solution (S.) ... 447
——Manganese in ferrovanadium. Clark ... 155
——Mercury in amalgamation tailings ... 896
——Nickel. Calhane ... 8
——Quantitative blowpipe Richards ... 137
——Spectroscopic steel ... 463
——Standardization of acid solutions. Randall and Scalione ... 787
——Sulphur dioxide method for hydro-carbon analysis. Rittman and Moore ... 713
Anderson, H. G. S. ... 402
ANILINE DYES:
——British industry ... 124
——Situation. Stone ... 663
——Situation before N. Y. Section Society of Chemical Industry ... 779
——Statistics. Stone ... 710, 828
Anodes, Manganese peroxide. Isherwood (P.) ... 641
Anodes for plating, Patents relating to. (D.) ... 403, 463, 575
Anti-dumping clause ... 705
ANTIMONY:
——Allotropy of. Vosmaer ... 536
——Electrolytic refining. Betts ... 848
——In Mexico ... 633

ANTIMONY: (Continued.)
——Mining in Japan 890
——Price changes 706
——Smelter 402
——Smelter on Pacific Coast 501
——Shipments from Central China 586
Applied Chemistry. Baekeland 677
Arc. Flaming. Carbons. Chemistry. Moore. 52
Arc. In vapors and gases at reduced pressures. Darrah 915
Archibald, W. M 978
Arcs. Unstable states in arc and glow. Cady 866
Argall, Philip 340
Argo Mill, Colorado 421
Arizona Copper Co 40, 207, 290, 535
Arizona smelters. Equipment 904
Aromatic compounds. Electrolysis of. Forbes 212
Armco iron 710
Armstrong, Theodore. (Photo) 130
Armstrong Cork & Insulation Co 792
Army and navy officers go to private plants 519
Aromatic hydrocarbons. Sulphur dioxide. Method of Determination. Rittman and Moore 713
Arsenic trioxide. Vapor pressure of 633
Asbes. Plant and wood for making potash. Bradley 841
Asphalt. Mining and preparing Trinidad. Pierce 697
Assaying. Cupellation losses. Sharwood. (S.) 927
Assaying. Wood-burning furnace. Edmands. (S.) 924
Assay Balance. Mechanical transference of weights 512
Association of Iron and Steel Electrical Engineers 392
Aston, James 340
ATMOSPHERIC NITROGEN FIXATION:
——Clennell 756
——Du Pont (P.) 642
——Landis (P.) 213
——Peacock (P.) 251, 642
——Russia 828
Atmospheric pollution of towns. Kershaw 967
Ault & Wiborg 691
Aurora Mill 16
Austria-Hungary. Chemical industries and the war. Donath and Ulrich. (S.) 639
Automatic Weighing Machine Co 691

B

BADGLEY, C. W 575
Baekeland, L. H. (Photo) 708
Bag house for lead smelter. (P.) 122
Bakelite. Suit decision 411, 592
Baker & Co., Inc 64
Baker-Hansen Co 745
Baker Mines Co 947
Baker, J. T., Chemical Co 691, 745
Baker, Charles W 820, 878
Baker, Robt. E 196
Balances. Analytical and laboratory. Christian Becker 631
Banks, John H 267
Barber Asphalt Company. Trinidad asphalt 697
Bardwell, Carlos 402
Bardwell, E. S 462, 520
Barium. Industry in U. S. Toch 710
Barytes 710
Base-metal situation 416
Battery. Two-fluid primary. Regeneration. Hess. (D.) 66
Bausch & Lomb Optical Co 644, 745, 802
Bauxite Production in 1914 546
Beach-Russ Co 691
Beauchamp, F. A 878
Beaver Consolidated Mines, L't'd 473
Becker, Inc., Christian 691
Beckers, W., Aniline and Chemical Works 691
Belmont Milling Co. Tonopah. Jones. (S.) 811
Bender, L. V 131
Bennett, F. A 267
Benson, H. K 646
Benzol plants 481
Benzol Products Co 691
Benzol from California oils 828
Benzol. Statistics 710
Berolzheimer, D. D 340
Beta Iron. Sauveur. (Poem) 352
Bethlehem Foundry & Machine Co 691
Bihn-Jones device for raising liquids 876
Bilharz, O. M 267
Birkinbine, J. L. W 820
Bismuth. Allotropy of. Vosmaer 535
Bit of economic mineralogy 581
Black Oak Mill. Palmer 622
Blake, Lucien I 196, 340
BLAST FURNACE:
——Blast efficiency and regulation. Burman 624
——Carbon bricks. Harden 202
——Charcoal. Wet ores in. Lee 882
——Chemical principles. Johnson ...536, 634
——Copper in Canada 16
——Filling of. Johnson 161, 227
——Handling iron and cinder Johnson. 43, 85
——Plant auxiliaries and general arrangement. Johnson ...373, 429, 495
——Thermal principles. Johnson 718 787, 833, 905
Blowpipe analysis. Quantative. Richards 137
Blue vitriol from Nichols Copper Co 484
Boiler feed water purification. Brown .. 156
Boiler feed pump 978
Boiler plugs. Tin. Investigation. Burgess. 712
Bolivia. Exports 15
Bomb calorimeter determinations. Effect of high ignition. Voltages. Dittus 480
BOOK REVIEWS:
——Abridged scientific—publications from the Research Laboratory of the Eastman Kodak Co 822
——American Fertilizer Handbook 772
——Bonini. I. Processi Termœlettrici della Si derurgia moderna Forni Elettrici 464
——Bühler. Filters and Filter Presses .. 198
——Camp. Analysis of Alloy Steels. Methods of the Chemists' Committee of the United States Steel Corporation 404
——Casterlin. Steel Working and Tool Dressing 578
——Clennell. The Cyanide Handbook ... 404
——Eckel. Iron Ores 342
——Ellis. Modern Technical Drawing .. 197
——Encken. Die Theorie der Strahlung und der Quanten 197
——Foerster. Electrochemie wasseriger Lösungen 772
——Frary. Laboratory Manual of Glass Blowing 268
——Gemeinfassliche Darstellung des Eisenhüttenwesens. (Compiled.) 578
——Giolitti. Cementation of Iron and Steel 520
——Grunwald. The Raw Materials for the Enamel Industry and Their Chemical Technology 342
——Hanemann. Einfuhrung in die Metallographie und Wärme Behandlung 578
——Hart. Welding 464
——Hays. How to Build Up Furnace Efficiency 404
——Heat Treatment of Steel. (Compiled.) 578
——Henault-Gall-Guye. Principes et applications de l'electrochemie 464
——Hofman. Metallurgy of Copper 66
——Hoover. Concentrating Ores by Flotation 342
——Ibbots and Aitchison. Analysis of Non-Ferrous Alloys 932
——Knox. Fixation of Atmospheric Nitrogen 197
——Megraw. Details of Cyanide Practice 577
——Meyer. Geschichte des Elektroeisens ...342
——Noyes. A Textbook of Chemistry 198
——Phillips and Orth. Mechanical drawing for colleges and universities. 980
——Pranke. Cyanamid 197
——Rodenhauser. Ferromangan als Desoxydationsmittel 464
——Rogers and Aubert. Industrial Chemistry 404
——Roush. Mineral Industry 822
——Searle. The Silicates in Chemistry and Commerce 198
——Sim and Wylie. Laboratory work for coal mining students 980
——Skinner. Mining Manual and Mining Year Book for 1915 646
——Skinner, Edmond Norton and H. Robinson. Plate-Mining Costs of the World 342
——Smith. The Sampling and Assay of the Precious Metals 578
——Turner. Molecular Association 878
——von Bernewitz, M. W. Cyanide Practice 1910-1913 577
——Wagner. Coal Gas Residuals 66
——Washburn. Principles of Physical Chemistry 932
——Watts. Laboratory Course in Electrochemistry 132
——White. Methods in Metallurgical Analysis 878
——Wilson, F. J. and I. M. Heilbron. Chemical Theory and Calculations 577
——Wittich. Joplin News Herald's 1915 Zinc and Lead Handbook 404
——Wright. Assaying, in Theory and Practice 342
——Wysor. Metallurgy 578
Borax industry. Current status. Dolbear 564
Boric Acid. Neutralization curve of. Prideaux 500
Boron Nitride. Manufacture. Weintraub. (P.) 763
Boronized cast copper. Weintraub 721
Boss mine 15
Bowles, James F. B 340
Bradford, Leslie 874
Bradley, George O 461
Branner, John C 267
BRASS:
——Electro-deposition. Rust. (D.) 196
——Experiences with in civil engineering. Flinn 712
——Failure of structural brass. Merica. 712
——Walenn 196
Braun Corporation 745
Brayton, Edward L 771
Breed, E. M 340
Briber, F. E 267
Brick. Manufacture and tests of silica brick. Seaver 861
Brinell principle testing machine 646
Briquet for use in zinc furnaces. Brooks. (P.) 451
Briquetting fine iron ore. (P.) 120
Bristol Company. Exhibit at San Francisco 398, 745, 832
Britannia linings for hardinge mills. Collins 650
British aniline dye industry 124
British Columbia Copper Co. Brunton. (S.) 509
British Dyes. L't'd 329
British dyestuff industry. Proposed 246
British producer gas and ammonia recovery plant. Lymn 456
Bronze. Aluminium. Bronze alloys. Corse 712
Bronze. Ampco 931
Bronzing processes suitable for brass and copper. Baker 254
Bronze castings as substitute for steel .. 193
Brown Instrument Co 691, 729
Bucyrus Company 585
Buffalo Foundry & Machine Company. 691, 914
Buffalo Mines, L't'd 472, 873
Bunsen Society meeting 965
Burch, Albert 131
Bureau of Mines 586
——Annual report. Holmes 84
——Dinner to Van H. Manning 979
——New director 654
——Outline of past and future service. Manning 652
——Publicity methods 199
——Studies sanitary conditions 577
Bureau of Standards 586
——Branch laboratories 403
Burgess, C. F. Laboratories 267
Burlingame, Walter E 575
Burro Mountain Copper Co. Ore treatment. Addicks 531
Butler, G. Montague 820
Butte-Duluth Mining Co 207
Butte & Superior Copper Company ...13, 207
Butte. Labor conditions 16
Buying and selling of ores and metallurgical products. Fulton (S.). 640
By-product coking 649
Byron Jackson Iron Works 745

C

CALCIUM carbide. Manufacture from carbide fines. Hartenstein (P.). 763
Cadmium. Allotropy. Vosmaer 953
Calcium carbide. New process. Becket. (P.) 642
Calibration. Curve for horizontal cylindrical tanks 511
California and the International Engineering Congress 579
California. Gold and petroleum yield in 1914 847
California. Mineral production in 1914 827
California Slime Extraction Co 617
Callow pneumatic process of flotation 571
Calorimeter determinations. Effect of high ignition. Voltages. Dittus 480
Caloris Company 279
Calorizing metals. Ruder 325
Calumet and Arizona Mining Co 473
Cameron, F. K 978
Cam for stamp mills. (S.) 118
Canada mineral production 662
Canada. Salt industry 846
Canadian Mining Institute 184
Capsule apparatus for sulphuric acid concentration. Mason 17
Carbolic acid 710
Carbolic acid. Extraction from oils of coal tar distillation. Mason 293
Carbolic Acid. Synthetic. Ney 686
Carbon. Determination by the combustion method. Jennings 70
Carbon. Electric furnace preparation. Hennebutte. (P.) 817
Carbon anodes in copper sulphate electrolysis. Addicks 748
Carbon bisulphide. Removal from Coal-gas 239
Carbon bricks for blast furnaces. Härden 202
Carbon dioxide tube lamp. Moore 885
Carbonitride manufacture. Peacock (P.). 642
Carbons, Chemistry of flaming arc. Moore 52
Carbon tetrachloride 710
Carborundum exhibit at Panama-Pac. Expos. 458
Cariman Mining and Milling Co 477
Carnotite ore treatment. Danforth, Samuels and Martersteck. (P.) 187
Carnotite ores. Concentration of 273
Carnotite. Extraction of radium, vanadium and uranium 965
Carstens, C. E 267
Case, Flotation testing machine 930
Casting iron. Johnson 43
Cast iron, Natural chill and its significance in the manufacture of malleable castings. Thrasher 39
Caustic soda. Continuous causticizing in Dorr apparatus 514

CAUSTIC SODA: (Continued.)
——Electrolytic production. Jewell (P.). 506
——Electrolytic production. Allen, Nelson and Jenkins. (P.)..... 815
Celluloid Zapon Co..... 691
Cement. New Plant of Consumers Portland Cement Co..... 846
Cement. Gun process for repairing coke-ovens 416, 529
——Schwarz 582
Centrifugals. Barnicke. (S.)..... 507
Centrifugal pumps 762
Centrifugal pump for thick liquors. D'Olier 512
Chain screen doors for furnace openings 875
Charlton, Thos..... 196
Chemical Catalog Company..... 691
Chemical Construction Co..... 846
Chemical engineering. Beilby..... 545
——Department at Columbia made independent 523
——Independent course at Purdue. Peffer 826
——Use of Hydrometallurgical Apparatus. Dorr 55
——Nitrocellulose manufacture. Stadelman 361
——Versus engineering chemistry. Palmer 203
Chemical industries. Accident prevention in. Keough 731
——In Austria-Hungary and the War. Donath and Ulrich. (S.)..... 639
——Germany. Frankland 378
——Opportunities for. Pratt..... 729
——Southwest, Resources and possibilities of. Baruch..... 604
——Status at close of 1915. Stone.... 710
Chemical principles of the blast furnace. Johnson 536, 634
Chemical reactions at low pressure. Langmuir 244
Chemical trade situation in Germany and Great Britain 59
Chemistry and lighting..... 50
Chemists' Club 691
Chicago Pneumatic Tool Co.....586, 832
Chilean nitrate exports to U. S..... 704
——Nitrate industry 15
——Nitrate statistics 402
——Nitrate producers debt..... 586
Chinese blue. Government corner..... 586
Chino Copper Co.....140, 527
Chloridizing at Park City, Utah..... 274
——New mill in Tintic district, Utah.. 889
Chloridizing roasting. Dudley 181
Chlorination of ores. McCaskell. (P.) 505
Chlorine. Electrolytic production. Allen, Nelson and Jenkins. (P.)..... 815
Chlorine production. Jewell. (P.)..... 506
Chromium production 484
Churchill Milling Co. Carpenter. (S.). 813
Cinnabar. Nevada Cinnabar Co..... 139
Cinnakol Chemical Sales Co..... 691
Clarage Fan Co..... 453
Clark, Geo. B.....878, 931
Classifier. Dorr 156
Clays. White-burning clays of the Southern Appalachian States. Watkins 179
Cleaning process. Electrolytic. Couch. (P.) 816
Cleansing by electricity. Burton. (D.) 131
Clerc, Frank L..... 267
Coagulation of albumin by electrolysis. Pancroft 317
Coal. Coking at low temperatures. Parr and Olin. (S.)..... 639
——Handling machinery 717
——Mining laws 832
——Nova Scotia and Newfoundland.... 887
——Powdered. At Anaconda. Mathewson 333, 728
——Powdered. Browne and Bender.... 182
——Powdered. Burning in reverberators. Browne 728
——Powdered. Reverberatory furnaces. (S.) 119
——Prices (London) 254
——Products and by-products..... 840
Coal and oil industry of Northwest. Benson 590
Coal Tar. Extraction of carbolic acid from oils of coal tar distillation. Mason 293
Cobalt 13
Cobalt. Electroplating with. Kalmus.. 328
Cobalt. Electroplating 840
Cobalt. Reduction of. (P.)..... 122
Cobalt. District shipments in 1914..... 207
Coffin, Howard E..... 708
Coffin, William C..... 646
Coghill, Will H..... 402
Coke. By-product coking..... 649
——Lack of coke and iron in Italy.... 577
——Ovens repaired by cement-gun process. 529
Coking of coal at low temperatures. Parr and Olin. (S.)..... 639
Coking coal land speculation..... 68
Collins, George E..... 820
Collins, L..... 820
Colloidal chemistry. Interesting application. Pierce 409
Colloids. Their action on ions during electrolysis. Mutsheller..... 353
——Transference of electricity. Powls.. 964
Color identity method of high temperature estimation. Patterson and Dudding 444
Colorado Fuel and Iron Co. Welfare work 234
Colorado Iron Works Company..... 196
Colorado-metal production in 1914..... 860
Colorado School of Mines..... 42
——Safety and efficiency engineering at 651
Columbia University establishes a separate department of chemical engineering 475, 523
Combustion method for the determination of carbon. Jennings..... 70
Combustion. Surface. Lucke 729
Coming society meetings 782, 884
Complex-ore problem. Is there a? Motherwell 8
Compressed-air gun 416, 529, 582
Compressor. Air. Nash Eng. Co..... 460
Concentrates. Parcel post ruling to affect shipment 526
CONCENTRATION:
——Butchart riffle system. (S.)..... 332
——Callow pneumatic process of flotation 571
——Carnotite ores 273
——Copper and the flotation process.... 133
——Crushing and screening at the Vindicator Consolidated mill..... 142
——FLOTATION:
—— Carbonates by previous conversion into sulphides. Terry. (P.) 63
—— Cons. Arizona Smelting Co.... 897
—— Cyanidation and flotation 880
—— Daly West Mill. Howard..... 600
—— Flotation as a conservation measure 345
—— Historical Notes 471
—— Joplin-Galena slimes. Belchic & Allen 847
—— Liquid jets. du Rell..... 714
—— Mixing drum. Callow. (P.).. 250
—— Park City 527
—— Results. Gahl 408
—— Silver King Coalition 509
—— Silverton, Col..... 348
—— Testing machine 930
—— Timber Butte Mill. Simons..189, 447
—— Suit 409
—— Tests on bisbee and cobalt ores. French. (S.) 509
—— Testing oils for flotation process. Coutts 389
—— Tube milling for flotation process. Easton 89
——Flow of sand and water through spigots. (S.) 120
——Nevada Consolidated Copper Co.... 716
——New riffling for tables..... 819
——Progress in ore-dressing in 1914.. 67
——Richards 728
——Riffling concentration tables 775
——Sulphuric acid. Mason 17
——Tube milling for flotation process. Easton 89
——Wilfley table riffles 577, 819
Concrete pumps 130
Condensation from steam-heating plants 335
Condensers. Barometric. Mesta Machine Co. 846
Condensers for evaporating apparatus. Kerr 551
Conduction through gases. Meeting of A. E. S. and I. E. S..... 884
Conductivities. Electric at high temperatures. Hering 23
Conductivity. Thermal. Of refractories. Dudley 315
Conductivity measurements 586
Congress. International Engineering Metallurgy at 655, 721
——Opening Welcome. Durant, Rolph, Moore, Goethals 655
——Copper 657, 721
——Fuel 728
——Gold and silver 721
——Iron and steel 655
——Lead 727
——Ore dressing 728
——Zinc 725
Coniagas Mines, Ltd..... 140
Connor, J. D..... 820
Consolidated Arizona Smelting Co. Flotation 897
Continuous causticizing. Dorr apparatus 514
Continuous filter 125
Converters. Copper in Canada 16
Contributions of chemistry to the industries of the U. S..... 269
——Hesse 287
Converter. Copper. With stationary hood. Howard. (P.) 924
Converter practice at Hayden, Ariz..... 585
Conveyor belt calculating chart..... 818
Conveyor belts. Gigantic. Goodrich.... 704
Cooper Co., C. & G..... 338
Co-operation in matters chemical. Herty. 588
Co-operation between university and industry. Meeting of American Chemical Society 885, 941
Copartnership in chemical industries. Lever 543
COPPER:
——Allotropy of. Vosmaer 536
——Application of chloridizing-roasting to separation of copper and nickel. Dudley 124
——Blast furnaces and converters in Canada 16
——Boronized cast. Weintraub..... 721
COPPER: (Continued.)
——British Columbia Co. Brunton. (S.) 509
——Continuous copper converter. Hass. (P.) 187
——Converter with adjacent stationary hood. Howard. (P.)..... 924
——Cyanide plating solutions. Weber.. 255
——Data on smelting furnaces..... 15
——Deposition from solutions from roasted ore. Tossizza (D.).. 132
——Design of modern copper plants. Repath 660
——Electrolysis of copper solutions containing ferric iron. Hybinette. (P.) 186
——Electrolysis of solutions. Addicks. (P.) 569
——Electrolysis of copper sulphate using carbon anodes. Addicks 748
——Electrolytic precipitation from cyanide solutions. Clevenger..... 803
——Electrolytic production of wire. (P.) 122
——Flotation of sulphidized minerals. Havland. (P.) 972
——Flotation process 133
——Hydrometallurgy 319
—— Ammoniacal solutions. Benedict 449
—— Bacon. (P.) 872
—— Chalcopyrite and chalcocite. Smith. (P.)..... 451
—— Copper ores. Austin..... 662
—— Goodrich. (S.)..... 766
—— Hybinette. (P.).....121, 569
—— Treatment of smelter flue dust and carbonate ore. Westby. 295
—— Van Arsdale. (P.)..... 63
—— Weidleins process 652
——Metallography. Campbell..... 721
——Metallurgy in Japan. Kondo..... 658
——Metallurgy. Progress in the Globe district, Arizona. Howard.... 659
——Metallurgy. Progress in. Read.... 657
——Metallurgy in the Southwest. Douglas 658
——Mining in Cyprus 425
——Oil-fired reverberatory smelting at Nev. Cons. Pomeroy. (S.)... 252
——Physical properties. Hayward..... 661
——Plating on joints of incandescent lamp. Edison. (D.)..... 932
——Porphyry coppers in 1914..... 348
——Precipitation by sulphur dioxide. Van Arsdale. (P.) 972
——Present tendencies in copper metallurgy. Mathewson 141
——Progress in 1914..... 5
——Purification of copper by iron or steel. Tassin. (P.)..... 186
——Refining—
—— Clark 661
—— Copper-nickel matte. Hybinette. (P.) 249
—— Martin and Jaeger. (P.)..... 816
—— Pyne and Green. (P.)..... 816
——Resumption of production in the West 349
——Roasting and leaching concentrator slimes tailings. Addicks 531
——Separation from iron and nickel. Borchers and Thilges. (P.).... 872
——Separation from nickel by chloridizing roast. Dudley..... 181
——Smelting—
—— Advances in. Laist..... 658
—— British Columbian Copper Co. Brunton. (S.)..... 509
—— Coal-dust fired reverberatory furnaces. (S.)..... 119
—— Copper Queen Consolidated smelter. Rutherford 659
—— Reverberatory practice at Nevada Consolidated 681
——Solution control in ferric-chloride leaching of sulphide ores. Flynn and Hatchett 291
——Stratification in electrolysis. Pyne.. 895
——Sulphatizing roast for copper ores. Carmichael. (P.)..... 186
——Sulphur dioxide in electrolytic process. Peneur Lloyd. (P.)..... 392
——Treatment of Michigan copper tailings. Leisk..... 233
Copper Sulphate. From Nichols Copper Co. 484
Cork exhibit at Pan.-Pac. Exposition... 459
Cornell. Russell T..... 461
Cornell. Sidney 461
Corrosion of gas and water mains by electrolysis. Yerbury..... 372
Corrosion problems before American Iron and Steel Institute..... 420
Corrosion of steel. Influence of composition. Aitchison 501
Corse. W. M..... 712
Costs as applied to professional businesses. Gould 603
Cottrell. Frederick G. Dinner to. (Photo) 81, 575
Cottrell electrical precipitation process. Bradley 697, 911
Counter-current decantation in cyanidation of slime. Pentland..... 105
Cowles. Russell A..... 771
Cox. W. R..... 931
Craven. Alfred 708
Cream tartar manufacture. Best..... 613
Crescent fuel oil engines 918
Cripple Creek high grade ore..... 201
Critical point determinations in iron, steel and alloys..... 643

Crocker-Wheeler Co. ... 745
Crowfoot. Arthur ... 267
Crown-Reserve Mining Co., Ltd. ... 207
Crushing. Hardinge mill data. Taggart. (S.) ... 566
Crushing. Heat developed in. Cook. (S.) 190
Crushing. Mills & Kuryla ... 721
Crushing. Plant of 1000 tons capacity. Bradley ... 721
Cryolite. Source of ... 720
Cunningham. Noel ... 131
Cupellation losses. Sharwood. (S.) ... 927
Cupels. Dixon's new ... 338
Cutler-Hammer Clutch Co. (Magnetic Separator.) ...770, 799
Cyanamide ... 756
Cyanamide process ...213, 243
——Washburn ... 309
Cyanide. Effect of enhanced value on silver ... 526
CYANIDE PROCESS:
See also Gold and Silver.
——Apparatus for cyaniding slime. Vandercook. (P.) ... 452
——Baker Mines Co. plant. Keeney ... 947
——Bullfinch Proprietary. Western Australia. Hay and Williamson. (S.) ... 331
——Chicksan mines. Korea. DeWitt. (S.) ... 388
——Churchill Milling Co. Carpenter. (S.) ... 813
——Cobalt ... 349
——Cyanide productions. Ruhl ... 13
——Effect of carbon in contact with solutions. Feldtmann. (S.) ... 389
——Effect of mineralized waters in cyanide mills. Stevens and Bradley. (S.) ... 389
——Effect of zinc prices on cyanidation. 406
——Electrolytic precipitation of cyanide solutions. Clevenger..725, 803, 852
——Filtration of slime. Mills ... 724
——Flotation of cyanidation ... 880
——Grinding ore for cyanidation. Modification for all sliming. Pettis. 9
——Grinding for all-slime practice. Pentland ... 205
——Hydrolysis of alkaline cyanides. Leslie. (P.) ... 972
——Liquid jets. du Rell ... 714
——Low grade sulphide ores in Colorado. Parmelee ...421, 477
——Pittsburgh-Dolores Mill ... 12
——Precipitation of gold from solution. Jolly. (S.) ... 61
——Precipitation. Towne and Robinson. (P.) ... 871
——Progress in 1914 ... 3
——Rand metallurgical practice. Bosgin. (S.) ... 925
——Slime agitation and solution replacement methods at West End mill. Carpenter ... 671
——Solution of gold and silver. Kuryla. 723
——Sons of Gwalia mines. Wauchope. (S.) ... 925
——Tonopah plant of Belmont Milling Co. Jones. (S.) ... 811
——Towne and Robinson. (P.) ... 871
——Treatment of arsenical-antimonial sulphide ore. Moore and Edmands. (S.) ... 508
——Tube milling in all-slime practice. Pentland ... 204
——Tube mill tonnage calculation. Cunningham ... 22
—— Haynes ... 10
——Vacuum slime filter. Osgood. (P.) 249
Cyanides. Canadian importation ... 717
Cyanides. Recent advances in manufacture. Clennell ... 756
Cyprus. Copper mining in ... 425

D

DALEY, J. C. ... 402
Daly West Mining Co., Utah. New mill. Howard ... 597
Daniels, Joseph ... 340
Dart, A. C. ... 931
De Beers, F. M. ... 462
Dehydrating petroleum oil. Laird and Raney. (P.) ... 570
De Laval Steam Turbine Co. ... 586
Denver Fire Clay Co. ... 914
De Sollar, Tenney C. ... 340
Detroit Range Boiler Co. ... 691
Development and control of industry by public influence. Armstrong... 544
Devine & Company, J. P. Exhibit ... 691
Diaphragm pump. For cyanide plants... 455
Die casting metal. New ... 931
Digest of electrochemical U. S. Panents. 65, 131, 196, 268, 341, 403, 463, 575, 771, 931
Direct electric lighting current adjusted to electro-analysis. Kauffman.. 524
Distillation of coal at low temperatures. Parr and Olin. (S.) ... 639
Distillation. Hardwood. French and Withrow ... 30
Withrow ... 797
Dixon Crucible Co., Joseph ... 745
D'Olier Centrifugal Pump & Machine Co. Pump for thick liquors ... 512
Dome Mines Co. ...16, 585
Dominion Coal Co. ... 887
Dorr, J. V. N. ...402, 462, 520, 771, 820, 978
Dorr hydrometallurgical apparatus..55, 91, 392, 514, 691, 745
Dorr agitators in series ... 13
Dorr apparatus for continuous causticizing ... 514
Dorr Thickeners at Nevada Consolidated. 716
Douglas, James ... 771
Dow Chemical Co. Making indigo..773, 776, 846
Driver-Harris Wire Company. Exhibit. 691, 847
Drop forged parts as a substitute for brass castings ... 400
Drucker, A. E. ... 131
Duplexing. Is it slated for assassination? Peyton. ... 397
Du Pont Chemical Company. Exhibit.. 691
Durex Chemical Works ... 710
Duriron Castings Co. ... 691
Dust collecting. The Fleming system. Hanna. ... 608
Dwight & Lloyd Sintering Co. ... 745
Dyes ... 760
——Aniline dye situation. Stone ... 663
——British industry ... 124
——British Dyes, Ltd. ... 329
——Pratt ... 730
——Proposed British industry ... 246
——Situation before Society of Chemical Industry, N. Y. Section....779, 829
——Statistics. Stone ...710, 829

E

EAKINS, L. G. ... 462
Edison, Thomas A. Exhibit ... 691
Edison, Thomas A. (Photo.) ... 708
Edison Storage Battery Co. ... 745
Efficiency in utilizing natural resources. Emerson ... 697
Eimer & Amend ...378, 691
Elastic strength of metals. Thompson.. 501
Electric arc in vapors and gases at reduced pressures. Darrah ... 915
Electric Heating Apparatus Co. ... 745
Electric smoke and fume precipitation... 160
Electric Weighing Co. Ampere-hour meter ... 191
Electrical controlling device. Pike-Sutton. (P.) ... 506
Electrical method of treating lumber. Sullivan. (P.) ... 506
Electrical precipitation of suspended matter. (P.) ... 122
Electrical precipitation of fume. Bradley ...697, 911
Electric treatment of emulsions and dusty gases. (P.) ... 122
Electro-analysis. Adjustment of direct electric lighting current. Kauffman. 524
——Determination of silver-arsenic-copper bismuth, antimony, tin, lead, and cadmium. Schoch. (S.) ... 568
——Nickel. Calhane ... 8
Smith ... 327
——Procedure. Schoch. (S) ... 568
Electrochemistry in America ... 1
Electrochemistry and lighting ... 884
Electrodynamometer instruments. New Weston ... 819
Electro-filtros. An improved diaphragm material. Thatcher ... 336
Electrolysis of copper sulphate using carbon anodes. Addicks ... 748
Electrolysis in concrete structures. Prevention by paints. Gardner. (S.) ... 391
Electrolysis of copper solutions. Addicks. (P.) ... 569
Electrolysis of copper solutions. Stratification. Pyne ... 895
Electrolytic method of sewage disposal. Olsen ...530, 735, 793
Electrolytic oxygen and hydrogen. I. O. C. system ... 585
Electrolytic precipitation of gold, silver and copper from cyanide solutions. Clevenger ... 852
Electrolytic purification of milk. Goucher. (P.) ... 506
Electromagnetic vacuum balance. Kelvin principle. Anderson ... 500
Electrometallurgy. Roeber ... 657
Electroplating. See Plating.
Electrotyping. Regulation of solutions. 258
El Paso. Lead smelting. Easter (S.).. 814
Elyria Enameled Products Co. ...586, 693
Emanuel, L. V. ...771, 931
Emmet, William Le Roy ... 708
Englehard, Chas. ...693, 745
Engineering chemistry vs. Chemical engineering. Palmer ... 203
Engineering English ... 799
Engineering foundation ... 80
Engineering or legal English ... 466
Engineering training. Fleming ... 371
Estabrook, W. A. ... 462
Etching of printing plates by electrolysis. Strecker. (D.) ... 132
Evaporation. Apparatus. Kerr. (S.).. 506
——Condensers. Kerr ... 551
——Vacuum pans. Kerr ... 485
Experimental furnace. High temperature. Malm ... 70
Export trade. Co-operation in chemical trade to South America ... 476
Exports and imports of steel ... 881
Exposition of chemical industries...351, 463, 465, 574, 629, 690
——List of exhibitors ... 691
——Official opening. (Doremus, Herty). 695
——Registration ... 734
——Second exposition ... 823
Exposition—Panama-Pacific 339, 398, 458, 743
Expositions and exhibits ... 648

F

FAIR protection for the American chemical manufacturer ... 705
Fairview Fluorspar & Lead Co. Exhibit. 693
Faraday Society ...173, 499, 962
Farnham, Frank R. ... 520
Federal Dyestuff & Chemical Co. ... 742
Federal mining experiment stations..139, 207
Federal investigation of smelters ... 274
Feldspar as a possible source of American potash. Cushman and Coggeshall. ... 99
Ferromanganese at Niagara Falls ... 482
Ferromanganese prices ... 585
Ferromanganese and manganese ore ... 575
Ferromanganese furnace at Noble Electric Steel Co. ... 484
Fertilizer industry of the Northwest. Benson ... 590
Fibre. Vulcanized. Almy ... 746
Fibrox. Weintraub ... 315
Field for engineers ... 406
Filteau, C. A. ... 196
Filter. Ore pulp. Lass. (P.) ... 972
Filtration apparatus for slime. (P.) ... 121
Filtration of slime. Mills ... 724
Filtration. Vacuum revolving filter. Faber. (P.) ... 569
Fink, Colin G. ...50, 697
Fire bricks. An examination of. Patterson ... 127
Beckett ... 136
First-aid field meet at San Francisco ... 652
Flaming arc carbons. Moore ... 327
Fleming dust collecting system. Hanna. 530, 609
Flexibility in finished steel production... 522
FLOTATION:
——Callow pneumatic process ... 571
——Carbonates by previous conversion into sulphides. Terry. (P.) ... 63
——Consolidated Arizona Smelting Co... 897
——Copper and the flotation process ... 133
——Conservation measure ... 345
——Cyanidation and flotation ... 880
——Daly West Mill. Howard ... 600
——Historical Notes ... 471
——Joplin-Galena slimes. Belchic & Allen. ... 846
——Liquid jets. du Rell ... 714
——Mixing drum for. Callow (P.) ... 250
——New testing machine ... 930
——Oils for ... 762
——Park City ... 527
——Results. Gahl ... 408
——Separation of lead and zinc. (S.).. 874
——Silver King Coalition ... 509
——Silverton, Col. ... 348
——Suit ... 409
——Sulphidized copper minerals. Hovland. (P.) ... 972
——Tests on Bisbee and Cobalt ores. French. (S.) ... 509
——Testing oils for flotation process. Coutts. (S.) ... 389
——Timber Butte mill. Simons. (S.) 189, 447
——Tube milling for flotation process. Easton. ... 89
Flow-sheets of organization ... 879
Fluorspar. Action on basic open-hearth slags. Hamilton ... 8
Hofman ... 136
Fluorspar statistics ... 717
Foote Mineral Co. Exhibit ... 693
Foreign markets for American chemicals. Norton. ... 758
Foundry and Machine Exhibition at Atlantic City ... 712
Franklin Institute lectures ... 782
Franklin, W. S. ... 771
Frary, Francis C. ... 820
French iron and steel industries and the war ... 371
French process for electrolytic zinc ... 888
Fritz medal presented to John Edson Sweet ... 75
FUEL:
——Coating for metal reduction furnaces. Kilbourn. (P.) ... 818
——Gas producer development. Kline.. 728
——in metallurgy ... 728
——Liquid fuel for furnaces. (P.) ... 121
——Oil fuel for heating, melting and heat treatment of metals. Best. (S.) ... 767
——Powdered coal at Anaconda. Mathewson ... 728
——Powdered coal in reverberatories. Browne. ... 728
——Supply contracts and the progress of more scientific methods of purchase and control in America and Europe. Kershaw ... 393
——Synthetic fuel oil. Snelling ... 180
——Use of peat ... 254

FUEL: (Continued.)
——Wood-burning assay furnaces. Edmands. (S.) 924
Fuller Engineering Co. 846
Fumes. Removal of sulphurous acid. Bergman and Berliner. (S.) ... 62
Fume problem. Electrical precipitation. Bradley 697, 911
Furnace-assay. Wood burning. Edmands. (S.) 924
FURNACE, BLAST:
——Blast-furnace plant auxiliaries and general arrangement. Johnson. 373, 429, 495
——Carbon bricks. Härden 202
——Chemical principles. Johnson...536, 634
——Copper in Canada 16
——Efficiency of the blast furnace operation. Burman 624
——Filling of. Johnson 161, 227
——Handling iron and cinder. Johnson. 43, 85
——Thermal principles. Johnson..718, 787, 833, 905
——Wet ores. Lee 882
Furnace. Combination gas and electric. Baily 560
Furnace. Comparative efficiency 357
Furnace curves. Weitlaner 425
FURNACE, ELECTRIC:
——GENERAL:
—— Acid process for steel. Müller. (S.) 640
—— Electric steel refining. Walker. (P.) 762
—— In the foundry. Kranz 565
*—— In the foundry. Petinot 650
Gosrow 882
—— Limitations in making steel castings. Lake 137
—— Compared with open-hearth for manufacture of commercial steels. Cornell 630
—— Preventing punctures in flame-arc furnaces. Troge. (P.) 763
—— Tapping device. Marshall. (P.) 872
—— Transformers 776
——VARIOUS DESIGNS:
—— Basic lined. Snyder 336
—— Determination of carbon and oxygen in steel and tungsten powder. Johnson 17
—— Casting. Queneau. (P.) 250
—— Electro-metals furnace of Grönwall, Linblad, Stalhane 371
—— Experimental high temperature. Malm 70
—— Ferromanganese at Noble Electric Steel Co. 484
—— Gold refining. Lass. (S.) 566
—— Heroult performance. Kranz... 565
—— Pure carbon. Hennebutte (P.). 817
—— Rennerfelt 702
—— Reheating, heat treating and annealing. Baily 558
—— Revolving tilted. Bunet. (P.).. 504
—— Steel. Stavanger Electrostaalverk 64
—— Temperature above 2000 deg. C.,
—— Zinc. Highfield. (P.) 817
——MANUFACTURE OF:
—— Abrasives. Kalmus. (P.) 762
—— Aluminum nitride. Bunet. (P.) 504
—— Boron nitride. Weintraub. (P.) 763
—— Calcium carbide. Hartenstein. (P.) 763
—— Calcium carbide. Becket (P.) 642
—— Carbon. Hennebutte. (P.)..... 817
—— Ferromanganese 484
—— Molded articles of silica, magnesia, etc. Hulbert. (P.).. 816
—— Refined steel castings. Snyder.... 336
—— Steel. Robertson 371
—— Steel castings. Muntz 108
—— Steel castings. Kranz 565
—— Steel castings. Petinot 650
—— Steels. Cornell 630
—— Steel by acid process. Müller. (S.) 640
—— Vanadium steel castings 501
—— Zinc. Johnson. (P.) 504
—— Manufacture of zinc. Ruhoff. (P.) 122
—— Zinc. Johnson. (P.) 763
—— Zinc. Highfield. (P.) 817
Furnace. Electrolytic. Manufacture of alkali and alkaline earth metals. Acker. (P.) 764
Furnace for heating billets. (P.) 121
Furnace. Gas-heated for producing alumina. Schwan. (P.) 569
Furnace. Lining by cement gun and torch. Schwarz. (P.) 250
Furnace. Metallurgical. Low-pressure oil burning 510
Furnace. Process of forming furnace walls. Hemmer. (P.) 251
Furnace. Open-hearth heating by tar. Greiner. 445
Furnace. Open-hearth compared with electric for steels. Cornell..... 630
Furnaces. Repairing with air guns..416, 582
Furnace. Reverberatory. Increase in Arizona. 904
Furnace. Reverberatory. Notes on. Pyne 292
Furnace. Reverberatory. Coal-dust fired. (S.) 119
Furnace. Roasting, using gas, oil or electricity. Wedge. (P.)..... 570
Furnace. Roasting. Effective heating of hearth. Wedge. (P.)..... 453
Furnace. Roasting, for zinc ores. Simmonds. (P.) 505
Furnaces. Roasting. Improvement in hearths. Klepinger and Corwin. (P.) 453
Furnace. Smelting. Operation to recover sulphur. Lamoreaux and Renwick. Hall. (P.)..... 452
Furnace. Wedge roasting furnace. (P.) 122
Furnace. Zinc. Briquet for use in. Brooks. (P.) 451

G

GALVANIZING angles and channels. Miller. (P.) 249
Galvanizing industry during the war.... 706
Garver, H. H. 267
Gas blowing engines at Pennsylvania Steel Co. 516
GAS:
——Analysis 851
——Bibliography of Manufacture..... 832
——British producer gas and ammonia recovery plant. Lymn 456
——Ignition by fracture of lamp bulbs.. 16
——Lead acetate test for hydrogen sulphide. (S.) 62
——Lymn producer-gas and ammonia plant 456
——Mantle, Incandescent. Chemistry of Miner 50
——Producer development. Kline..... 728
——Producer efficiency. Important advance 399
——Wood-gas generators. Wanchope. (S.) 874
Gasoline manufacture from petroleum oils by aluminum chloride process. McAfee 592
Gasoline vapor and air mixtures..... 802
Geissinger Regulator Co. Exhibit..... 693
General Bakelite Co. 693
General Chemical Co. 693, 967
Gerdes & Company. 693
Germany and Great Britain chemical trade situation 59
Germany. Chemical industries. Frankland 378
Gibbs-Willard. Professorship of research in pure chemistry 828
Gibbs adsorption formulas. Harlow and Willows 499
Gibbs Instrument Co. 288
Glass industry. Chemistry and mechanical manipulation. Frink..... 800
Glass melting. Knoblauch. (S.)..... 568
Glassware for laboratories..... 444
Glens Falls Machine Works..... 693
Glucose. Commercial. Rolfe. (S.).... 332
GOLD AND SILVER:
——Acid treatment of gold precipitate. (S.) 118
——Agitator for ore treatment. Dorr. (P) 392
——Agitator for slime pulps. Vandercook. (P.)..... 924
——Amalgamation tests. Sherwood. (S.) 927
——Apparatus for cyaniding slime. Vandercook. (P.)..... 452
——Assay of gold-bearing cyanide solution. Levy and Jones. (S).... 447
——Automatic regulation of thickener. Dorr. (P.) 452
——California gold yield in 1914..... 847
——Chlorination of ores. McCaskell... 505
——Churchill Milling Co. Carpenter (S) 813
——Coarse crushing plant of 1000 tons capacity. Bradley. 721
——Combination of precipitation and filtration in cyaniding. Mills. (P.) 186
——Complex ore problem. Motherwell. 8
——Concentration of gold in bottoms in the copper converter. Collins. (S.) 446
——Consulting metallurgist and metallurgical investigations. Blyth. (S.) 251
——Continuous agitation. Robinson. (P.) 871
——Crushing and grinding. Mills and Kuryla 721
——Cupellation losses. Sharwood (S.). 927
——Cyaniding at Bullfinch Proprietary, Western Australia. Hay and Williamson (S.) 331
——Cyaniding at the Chiksan mines, Korea. DeWitt. (S.)..... 388
——Cyaniding at Cobalt..... 349
——Cyaniding process. Towne and Robinson. (P.) 871
——Cyanide production 13
——Determination in cyanide solutions. Bahney. (S.) 252
——Effect of carbon in contact with auriferous cyanide solutions. Feldtmann. (S.) 389
——Electrolytic precipitation of cyanide solutions 803, 853
——Clevenger 725
——Filtering apparatus. (P.)..... 121
——Filtration of slime. Mills..... 724
——Flotation in gold metallurgy. Blyth 308
——Gold deposits in assay office..... 16
——Gold dissolved in slime residue. (S.) 119
——Gold refining with an electric furnace. Luss. (S.)..... 566
GOLD AND SILVER: (Continued.)
——Gold milling in California. Palmer. 617
——Grinding ore for cyanidation. Modification for all sliming. Tettis.. 9
——Hydrolysis of alkaline cyanides. Leslie (P.) 972
——Improved cam for stamp mills. (S.) 118
——Metallurgical practice in the Porcupine district. Cunningham. (S.) 187
——Notes on Homestake metallurgy. Clark (S.) 764
——Pittsburgh-Dolores mill..... 12
——Precipitation of gold from solution. Jolly. (S.) 61
——Precipitation process. Towne and Robinson. (P.) 871
——Progress of metallurgy in 1914..... 3
——Rand practice review. Bosqui. (S.)..925
——Recovery of mercury from cobalt silver amalgamation residues. Thornhill. (S.) 330
——Recovery of mercury from amalgamation tailing. Thornhill. (S.) 873
——Refining gold by Miller chlorine process. Pearson. (S.)..... 508
——Relative efficiency of various amalgams. Thomson and Keffer... 367
——Silver sidewalk 890
——Smelting and refining of cobalt-silver ores. Phillips. (P.)..... 186
——Solution of. Kuryla 723
——Sons of Gwalia Mine. Wauchope. (S.) 925
——Tonopah plant of Belmont Milling Co. Jones. (S.)..... 811
——Transvaal gold production....15, 425, 529, 745
——Tube mill tonnage calculation. Cunningham 22
—— Haynes 10
——Vacuum slime filter. Osgood. (P.). 249
——Vacuum slime filter. Trent. (P.).. 185
——Vacuum filter. Faber. (P.)..... 569
——Zinc alloy for precipitation of cyanide solutions. Clevenger. (P.) 185
——Zinc precipitation tests. Herz. (S.) 973
Goodale, C. W. 131
Goodrich conveyor belts. Gigantic..... 704
Goodrich Co.'s belt chart..... 818
Government aid for scientific research (London) 502
Government publicity methods. Snelling 273
Graphite 734
Graphite brushes 745
Graphite and magnesia. Reaction between. Kawalke and Grenfell.. 316
Graphite. American production..... 526
Great Britain and Germany. Chemical trade situation 59
Great Britain. Notes on chemistry and metallurgy.....123, 254, 329, 370, 443, 502, 583, 778, 869
Green, L. M. 131
Greiner Co., Emil. Exhibit..... 693
Grondys, H. F. 65
Gross, John 878, 931
Guernsey & Co. 745
Guess, Harry A. 978
Guiterman, Franklin. Obituary..... 352
Guy, A. E. 402

H

HAGAN American underfeed stokers.... 64
Hall, Charles M. Photo..... 130
Hall, John H. 340
Hamilton, Edward 771, 820
Hamilton, E. M. 878
Hanovia Chemical Co. 693
Hansell, N. V. 131
Hardening of metals before the Faraday Society 173
Hardinge, H. W. 65, 402
Hardinge amalgamator 279, 618
Hardinge mill data. Taggart. (S.)..... 566
Hardinge Conical Mill Co. 586, 745
Hardinge conical mills. Britannia linings for. Collins..... 650
Hardwood distillation industry in America. French and Withrow..... 30
Hardwood distillation industry. Withrow 797
Hardy, Edward 771
Haynes, Justin H. 575
Heating of mines. Cadinaw..... 254
Heat treating. Electric furnace for. Bailey 558
Hedges, B. F. Zinc oxide at South Chicago 783
Hegeler, Julius W. 65
Heinz, N. L. 520
Heller & Merz Co. Exhibit..... 693
Hering, Carl 267
Herold China & Pottery Co. 257
Herr, Donald D. 196
Herty, C. H. 646
Heusser, Wilfred. Inventor of new assay balance 512
Hewitt, Peter Cooper. Photo..... 709
Hibbard, Henry D. 820
High temperature estimation by color identity method. Patterson and Dudding 444
High temperature measurements course at Purdue. Ferry 454
High-temperature physical problems. Northrup 147
Hollinger Gold Mines, Ltd. 140, 638
Holmes, Joseph Austin..... 519

Homestake metallurgy. Clark. (S.).... 764.
Houle, Albert J..... 462
Howard, H. O..... 820
Howbeet, V. D..... 267
Huff Electrostatic Separator Co. Exhibit 693
Hunt, Andrew M..... 708
Huntington, W. C..... 267
Hutchinson, J. W..... 131
Huyck & Sons, F. C. Exhibit..... 693
Hyde, James M.....65, 402
Hydraulic forcing and miscellaneous presses 391
Hydraulic disruption in mining. Tonge.. 124
Hydraulic hardness testing machine..... 646
Hydrocarbons. Aromatic estimation of in cracked petroleum. Rittman, Twomey, Egloff..... 682
Hydrocarbons. Sulphur dioxide method for determination of aromatics in hydrocarbon mixtures. Rittman and Moore 713
Hydrochloric acid electrolysis. Jeffrey.. 964
Hydrogen. Electrolytic. Plecher. (D.).. 65
Hydrogen manufacture. Fourniols (S.). 567
Hydrogen peroxide by electrolysis. Weber. (P.) 641
——Thermal decomposition. Clayton..... 964
Hydrogen sulphide in gas. Lend acetate test. (S.) 62
Hydrogenation of fatty oils. Catalyser for. Ellis. (P.)..... 700
Hydrometallurgical apparatus in chemical engineering. Dorr 55, 91
HYDROMETALLURGY:
——Arizona copper ore. Goodrich. (S.). 766
——Copper ores. Hybinette. (P.)..... 569
——Copper ores. Austin..... 662
——Copper. Weidlein's process..... 652
——Copper 319
——Copper with ammoniacal solutions. Benedict. (P.) 449
——Solution control in ferric-chloride leaching of sulphide copper ores. Flynn, Hatchett 291
——Roasting and leaching concentrator slimes tailings. Addicks..... 531
——Treatment of Michigan copper tailings. Leisk 233
——Zinc-lime ore with acids. Ralston and Gartside 150

I

ILLUMINATING engineer and ideal light. Ives 327
Illumination. Gaseous electric, Moore.. 55
Illuminating engineering society..... 884
Illium 973
Imperial vacuum pumps (Ingersoll-Rand) 769
Imports and exports of steel..... 881
Inclusions in steel. Comstock..... 891
Indigo. Made in U. S.....773, 776, 846
Industrial chemistry. Some American contributions to. Sadtler..... 700
Industrial chemistry. Baekleand..... 677
Industrial energy as a military weapon. Finlay 547
Industrial Instrument Company..... 64
Industrial resources and opportunities of the South. Little..... 281
Industrial resources and opportunities of the Northwest. Benson..... 589
Ingersoll-Rand "Imperial" vacuum pumps 769
Inspiration Consolidated Copper Co..... 349
Institute of Industry and Commerce. (London) 254
Institute of Metals (London).....254, 371
Institution of Mechanical Engineers (London). Research work..... 444
Insulating brick 129
International commerce 444
International Engineering Congress, 351, 546, 579
——Abstracts of papers..... 655
International Filtration Corporation. Exhibit 693
International Instrument Co. Exhibit.... 693
International Oxygen Co..... 792
Inventions. Danger of throwing them open to the public. Hibbard.... 206
Ionium. Atomic weight..... 966
Ions. Action of certain colloids during electrolysis. Mutscheller 353
Ions. Relative migration velocities in complex electrolytes. Mutscheller 439
Iridescent coating on metals. Sinclair. (D.) 132
Iron and Steel Institute (London)..... 254
——First day's meeting..... 445
——Second day's meeting..... 502
IRON AND STEEL:
——1914 the steel trade's poor year..... 7
——Action of fluorspar on basic open hearth slags. Hamilton..... 8
——Acid process. Müller. (S.)..... 640
——Alloy for dynamo-electric purposes. Rübel (P.) 249
——Alloy steels. Norris..... 739
——Alumina in steel. Comstock..... 891
——Alumina in 933
——Bessemer and open hearth steel..... 465
——Bessemer steel 774
——Blast furnace plant auxiliaries and general arrangement. Johnson. 373, 429, 495
——Briquetting fine ore. (P.)..... 120
IRON AND STEEL: (Continued.)
——Carbon bricks for blast furnaces. Harden 202
——Carbon determination by the combustion method. Rich..... 347
——Carbon determination using platinum boats. Siever 525
——Case hardening of steel. Giolitti..... 656
——Castings. Hall 655
——Chemical principles of the blast furnace. Johnson.....536, 634
——Combustion apparatus for carbon analysis. Cox. (P.)..... 504
——Determination of carbon and oxygen. Electric muffle furnace. Johnson 17
——Determination of chromium and vanadium. Rich-Whittam 238
——Determination of critical points..... 643
——Distribution of steel..... 270
——Duplex steel process. Lines..... 656
——Efficiency of the blast furnace operation. Burman 624
——Electric furnace steel making. Gray. 656
——Electric furnace for steel castings. Muntz 108
——Electric steel furnace..... 402
——Electric steel in Germany and Austria 398
——Electric steel making furnace..... 371
——Electric steel refining..... 336
——Electric steel refining. Walker. (P.) 762
——Electrometallurgy. Roeber 657
——Filling of blast furnace. Johnson. 161, 227
——Finishing temperature of rails. Shimer 178
——Flexibility in finished steel production, 522
——Furnace for heating billets. (P.)..... 121
——Handling iron and cinder at the blast furnace. Johnson.....43, 85
——Hardening of metals. Faraday Society 175
——Heat treatment of automobile gears. Abhot. (S.) 390
——Heating an open-hearth furnace with tar. Greiner 445
——High blast heats in Mesaba practice. Forbes 177
——How the steel market is made..... 934
——Imports and exports of steel..... 881
——Influence of composition on corrosion of steel. Aitchison..... 501
——Influence of titanium on steel. Fitz-Gerald 28
——Interlocking brick for hot-blast stoves. Slick (P.)..... 249
——Iron-boron-carbon-copper alloy. Gleason. (P.) 185
——Iron in Lake ores..... 343
——Iron in Utah..... 890
——Iron industry of Brazil..... 403
——Iron industry making new records.. 707
——"Ironized" steel tubes..... 15
——Iron trades divergences under war demand 581
——Lack of coke and iron in Italy..... 577
——Lake Superior iron ore prices..... 933
——Limitations of the electric furnace in the manufacture of steel castings. Lake 137
——Liquid fuel for furnaces. (P.)..... 121
——Low phosphorus steel. Dinkey. (P.) 971
——Magnetite coating on iron. Hollis, (D.) 65
——Magnetic habits of alloy steels. Mathews. (S.) 187
——Making steel alloys. Smith (P.)..... 391
——Making manganese steel from scrap. (P.) 121
——Market report..14, 72, 194, 208, 275, 349, 417, 473, 527, 653, 711, 776, 831, 889, 939
——Metallography and the hardening of steel. Sauveur 655
——Modified iron-carbon diagram. Sperry 469
——Natural chill of cast iron and manufacture of malleable castings. Thrasher 39
——New Jersey mines active..... 755
——Nova Scotia and Newfoundland..... 887
——Open hearth versus electric furnace. Cornell 630
——Pig iron statistics, 1914..... 200
——Plating or galvanizing machine. Miller. (P.) 249
——Possible applications of oxygen. Johnson 483
——Preventing piping in steel ingots. Gathmann 656
——Process for dephosphorizing pig iron. Pasquier. (P.) 570
——Process of treating cast iron for removing oxygen. Johnson. (P.).. 701
——Productive capacities in the iron and steel industry 880
——Removing rings from nodulizing kilns. (P.) 121
——Scale removed by pickling. Hering.. 785
——Scientific study 877
——Sintering ores. Plock. (P.)..... 452
——Sintering fine ore. Krom. (P.)... 185
——Sound steel ingots and rails. Burgess and Hadfield 178
——Sound steel ingots and rails. Hadfield and Burgess 445
——Spectroscopic steel analysis..... 463
——Steel alloys. Norris 656
——Steel capacity and demand..... 523
——Steel famine possible..... 775
——Steel manufacture. Brown. (P.)... 817
——Steel refining. Walker. (P.)..... 391
IRON AND STEEL: (Continued.)
——Steel corporation allowed to live.... 407
——Steel shape and rod production—1914. 405
——The steel industry and the war..... 466
——Thermal principles of the blast furnace. Johnson 718
——Titanium alloys for baths. Goldschmidt-Weil. (P.) 641
Transformation of pure iron. Faraday Society 962
——Treating mill scale. Becket. (P.)....391
——Unprecedented times in steel 823
——U. S. Steel corporation operations in 1914 201
——Vanadium from oxide to steel. Bleecker and Morrison 492
——War and the French industries..... 371
——War and American iron trade..... 134
——Work at National Physical Laboratory (London) 584
"Ironized" steel tubes 15

J

JAPAN. Copper metallurgy. Kondo.. 658
Japan's activity in mining..... 608
Johns-Manville Co..... 745
Johnson Engineering Co..... 860
Johnson, J. E., Jr.....340, 771, 978
Johnson, W. McA..... 65
Jones, Archibald 520
Jones, Jesse L. 712
Joplin zinc and lead ore output..... 472

K

KAPTEYN, G. J. 131
Kee, W. J., Jr..... 267
Keeney, Robt. M. 771
Keller, A. E..... 65
Keller Mfg. Co. 745
Kelley, C. K..... 131
Kelly Filter Press Co..... 392
Kelp industry in Scotland 443
Kemp, James F..... 340
Kieselguhr Co. of America..... 693
Kiessig, Charles H..... 980
Kondo, Wasata 820
Kranefeld, P. 931
Krecji, Milo W. 520
Krell, Phillip J. 931
Krogh Pump Mfg. Co..... 745
Kuchs, O. M..... 131

L

LABORATORIES. Burgess. 267
Laboratory glassware 444
Laist, Frederick 131
Lamme, Benjamin G. 708
Lamp-Quartz mercury-vapor. Maily..... 55
Lamps, electric, new 884
Lamp filaments, Tungsten for. Gmür-Zehnder. (P.) 924
Lamp filaments. Zirconium-iron alloy. Brown. (P.)..... 924
Landreth process of sewage disposal. Olsen 736
Latent heat of dilution. Porter..... 499
Lawler, Edw. W. 267
Lawrence, B. B. 979
Lea-Courtenay Co. 762
Le Clanche cells. Thompson and Crocker. 319
Lead acetate test for hydrogen sulphide in gas. (S.)..... 62
LEAD:
——Allotrophy of. Vosmaer..... 953
——Bag house for lead smelter. (P.)... 122
——Coated fuel for reduction furnaces. Kilbourn. (P.) 818
——Desilverization. Newton 181
——Electrolytic deposits. Mathers and McKinney 328
——Electrolytic refining. Betts. (D.).. 132
——High lime slags in smelting. Bretherton. (S.) 766
——Newnam mechanical hearth. Newnam. (S.) 974
——Poisoning in manufacture of storage batteries 347
——Price changes 706
——Sampling bullion 930
——Separation from zinc by flotation. (S.) 874
——Smelter bag house. (P.)..... 132
——Smelting at El Paso. Easter. (S.). 814
——Smelting at Salida smelter. Weeks. (S.) 814
——Smelting and refining. Hofman..... 727
Lead Lined Iron Pipe Co. Exhibit.... 693
Leadville. Production of zinc oxide from low-grade carbonate ore... 631
Leitz, Ernst 745
Lenz and Naumann. Exhibit..... 693
Liberty Bell mine..... 392
Library service bureau of United Engineering Societies 366
Licenses for Colorado ore buyers..... 651
Lighting and chemistry 50
Lighting of electrolytic tank rooms..... 327
Lime. Production in 1914..... 832
Lime. Reburning from alkali waste and other forms of carbonate of lime. Meade 289

Link-Belt Company 585
Liquid jets. du Rell 714
Little confusion of thought and speech.. 824
Little, Arthur D..... 340
"Little Journal" 15
Locke, Charles E..... 520
Low-grade and complex ores of Utah, Metallurgy 472
Low-pressure oil-burning metallurgical furnaces 510
Lumber industry of the Northwest. Benson 590
Lummus, W. E..... 520
Lungwitz, Emil E..... 340
——Exhibit 693
Lymn producer—gas and ammonia plant 456
Lyon, Dorsey A.....462, 575

M

MACBETH-EVANS GLASS CO. Exhibit 693
Mackay School of Mines..... 12
Magnetic separation outfit. Cutler-Hammer 770
Magnetic separator pulleys. Cutler-Hammer 799
Magnetite coating on iron. Hollis..... 65
Magma Copper Co..... 139
Magnesia and graphite. Reaction between. Kowalke and Grenfell 317
Magnesium 141
Magnesium chloride solutions. Temperature of hydrochloric acid formation in evaporating. Hof. (S.) 508
Magnesium. Electrolytic preparation. Frary and Berman 324
Magnetic separation of white metal and gun metal borings. Walton-Bailey 204
Magnetic separation of zinc-iron sulphide ores 573
Magnus, Benjamin 462
Malleable castings. The natural chill of cast-iron. Thrasher 39
Malm, John L.....65, 267
Mammoth Copper Mining Co..... 745
Manganese for chemical trade from Colorado 415
Manganese in ferro-vanadium. Clark... 155
Manganese ore in 1914..... 146
Manganese ore and ferromanganese statistics 575
Manganese peroxide anodes. Isherwood. (P.) 641
Manganese steel from scrap. (P.)..... 121
Manning, Van. H..... 654
——Dinner to 979
Mantle. Incandescent gas. Chemistry. Miner 50
Marcy, F. E.....820, 878
Markets. Foreign. For American chemicals. Norton 758
Market. Iron and steel..14, 72, 194, 208, 275, 349, 417, 473, 527, 653, 711, 776, 831, 889, 939.
Market. Non-ferrous metal..14, 75, 146, 208, 294, 350, 461, 474, 527, 831, 890, 939
Market prices (London)..124, 330, 446, 503 585, 778, 871.
Marr, Robt. A..... 196
Materials of engineering construction.. 572
Mathews, John A..... 979
Mathewson, E. P..... 131
Matthew, H. T..... 462
Maxim, Hudson 708
McCann, Ferdinand 462
McCarthy, James F..... 820
McFarlan, Edward 820
McKee, Arthur G..... 196
McKennan, J. B..... 520
McKinley-Darragh-Savage mines 473
McNair, F. W..... 575
Meade, Richard K..... 820
Mechanical analogies in electricity. Franklin 317
Meetings. Coming 884
Mellon Institute of Industrial Research 146
Mellon Institute. Dedication of new building. Hamor 266
Melting points of elements..... 302
Menk, C. A..... 821
Merck & Co. Exhibit 693
Mercury. Extraction. Thornhill. (P.).. 63
——Production 18
——Production in Austria in 1913..... 631
——Recovery from cobalt-silver amalgamation residues. Thornhill. (S.) 330
——Recovery from amalgamation tailing. Thornhill. (S.) 873
Mercury. Vapor lamp. Quartz 55
Merrill Metallurgical Co..... 745
Mesereau Gail 519
Mesothorium 735
Mesta Machine Co.....586, 846
Metallographic tests. Preparation of specimens 400
Metallography. Copper. Campbell 721
Metallography and the hardening of steel. Sauveur 655
Metallography. Improved photomicrographic apparatus 928
Metallography. What it can show. Fitz Gerald 936
Metals. War consumption of. Ingalls.. 550
Metal industries. Effect of war on. Wettstein 712
Metal ornamentation. Eppler. (D.)..... 131
Metal production statistics for 1914.... 98
Metallurgical and chemical engineering. Exhibit 693
Metallurgy. Present importation of.... 522
——At International Engineering Congress 721
——Co-operative exhibit at Panama-Pacific Exposition. Wells and Clevenger 535, 743
Metastability of metals. Vosmaer..... 953
Mexico. Conditions in.....209, 270
Mica in 1914 792
Migration velocities of ions in complex electrolytes. Mutscheller 439
Mill scale. Treatment of. Becket. (P.) 391
Miller, Spencer 708
Mine explosions. Prevention of..... 123
Mine & Smelter Supply Co. New Heusser balance. 512
——Willey 819
Mineral industries of Northwest. Benson 591
Mineral Products Co..... 526
Minerals Separation Co. process..... 897
Mines. Heating of. Cadinaw..... 254
Mining activity in Japan..... 608
Mining and Metallurgical Society of America 116, 887
Mining and milling 180
Mining exhibits at Panama-Pacific Exposition 460
Mining. Hydraulic disruption in. Tonge 124
Mining statutes annotated..... 762
Missouri. Production of lead and zinc 29
Mistakes. Make them on a small scale.. 825
——Heynemann 936
Mogul Company. Exhibit 693
Molybdenite 799
Molybdenum. Extraction. Robertson. (P.) 64
Molybdenum in Colorado 12
Monarch Engineering Co..... 745
Monazite 735
Monazite sand in Brazil..... 150
Monazite sands. Brazilian, analysis of 403
Monel metal. Failure of the Sea Call.. 884
Monitor Belmont Mining Co..... 425
Monsanto Chemical Works. Exhibit.... 693
Montana Tonopah Mines Co..... 417
Montgomery, H. M..... 520
Mooney, J. P.....267, 931
Moore tube lamps 885
Morgan gas producer 399, 641
Morse, Philip S..... 196
Morse Bros. Machinery and Supply Co. 557
Motors. Industrial applications in chemical and metallurgical industries. Barnes 297
Mott Iron Works, J. L. Exhibit 693
Mount Lyell. Pyrite smelting..... 116
Mount Morgan Gold Mining Co..... 140
Multiple-type recording instrument for pyrometers 643

N

NAPHTHALENE. STATISTICS..... 710
Nash Engineering Co. Centrifugal Pump. 460
National Association of Manufacturers. Keough 731
National Engineering Co..... 586
National Aniline and Chemical Co. Exhibit 693
National Exposition of Chemical Industries.....351, 463, 465, 574, 629
National Forcign Trade Council..... 122
National Physical Laboratory (London) 1914-15 .....583, 870
National plant. American Smelting & Refining Co. 783
National Tube Co..... 586
Natural gas 586
Naval Advisory Board..... 686
Naval Consulting Board. Vogt..... 827
——Backeland 943
——First meeting and first recommendation 708
Naval Research Laboratory..... 709
Negru, Jacques 196
Nehls Alloy Co. "Sentinel" Pyrometers. 192
Neutrality of science. Richards..... 408
Neutralization curve of boric acid. Prideaux 500
Neutralization of absorbed ions. Bancroft. 318
Nevada. Mineral production..... 15
Nevada Cinnabar Co.....16, 138
Nevada Consolidated Copper Co..139, 252, 527
——New club house for employees..... 652
——Notes on concentration..... 716
——Reverheratory smelting practice..... 681
Nevada. Douglas Cons. Copper Co..... 274
Nevada State mining laboratory..... 110
New Jersey iron mines..... 755
Newhouse, Edgar L..... 196
Newnam mechanical hearth. Newnam. (S.) 974
Newspaper chemistry 463
Newspaper chemistry of platinum..... 525
Newspaper mineralogy 581
Newton, F. C..... 771
Niagara Falls. Energy export from Canada. 42
Niagara Falls Section of the American Electrochemical Society. (Organizing meeting.)..... 651
Nice, Paul S..... 196
Nichols Gold Medal to Irving Langmuir.. 244
NICKEL:
——Application of chloridizing-roasting to separation of copper and nickel. Dudley 124
——Electro-analysis. Calhane..... 8
——Refining copper-nickel matte. Hybinette. (P.)..... 249
——Separation from copper. Borchers and Thilges. (P.)..... 872
——Welding scrap anodes..... 453
Nickel-chromium resistor suit..... 414
Nipissing Company 15, 275
Nitrate industry of Chile..... 15
Nitric acid. Electrolysis. Jeffery..... 964
Nitrocellulose manufacture. Stadelman.. 361
NITROGEN, ATMOSPHERIC FIXATION:
——Aluminium nitride manufacture. Bunet. (P.)..... 504
——du Pont. (P.)..... 642
——Clennell 756
——Landis 213, 325
——Peacock. (P.).....251, 642
——Russia 828
Nitrogen problem. Essay on..... 573
Nobel prize awarded to Theodore W. Richards 884
Noble Electric Steel Co. Ferromanganese furnaces 484
Non-ferrous metal market.....14, 75, 146 208, 294, 350, 461, 474, 527, 831, 890, 939.
Non-ferrous metals during the war..... 706
Non-ferrous metallurgy 181
Northwest. Industrial resources and opportunities. Benson..... 589
Norton Co. Exhibit..... 693
Norton, L. H..... 979
Norwegian electric steel plant..... 64
Nova Scotia Steel & Coal Co..... 887
Noyes, Arthur A..... 462
Nungesser Carbon & Battery Co..... 460

O

OHIO COPPER CO..... 585
Oil 254
——Catalyzer for hydrogenation. Ellis. (P.) 700
——Dehydrating petroleum oil. Laird-Raney. (P.)..... 570
——Drying and purifying outfits..... 977
——Fuel for heating and melting metals. Best. (S.)..... 767
——Flotation 762
——Metallurgical furnaces. Case..... 510
——Oil-fired furnaces at Nevada Cons... 681
——Pipe line in California..... 529
——Synthetic fuel. Snelling..... 180
Oliver Continuous Filter Co..... 745
Oneida Community, L't'd..... 279
Opportunities for the American chemical industry. Pratt..... 729
Ores. Wet. In charcoal blast furnace. Lee 882
Ore-dressing. Richards 728
Ore-dressing. See Concentration.
Organic electro-chemistry. Commercial aspects. Lidbury..... 211
Ormsbee, James J..... 931
Osmiridium. Recovery in mint..... 16
Osmosis. Removal of water from pulp, peat, etc. Schwerin. (D.)..... 66
——Situation at close of 1915..... 710
Oxygen and hydrogen. Casselberry and Edgerton. (D.) 772
Oxygen. Electrolytic. Flecher. (D.)... 65
Oxygen and hydrogen. Electrolytic..... 585
Oxygen. Possible applications in metallurgy. Johnson 483
Oxy-acetylene. Portable welding outfit... 194
Oxy-acetylene welding. (Prest-O-Lite.).. 770
Oxy-benzyl-methyel-englycol-anthydride .. 592
Oxy-hydrogen. Cells for Japan..... 501
Ozone for ventilation 975

P

PACIFIC TANK & PIPE CO..... 745
Paint. Heckel 807
Paint remover patent decision..... 129
Palladium. Recovery in mint 16
Palmer, Irving A..... 520
Panama Canal Commission award..... 499
Panama-Pacific Exposition. What it means to the metallurgical and chemical engineer 339
——Award to Met. & Chem. Eng..... 460
——Carborundum exhibit 458
——Cork exhibit 459
——Metallurgical exhibit. Wells and Clevenger 743
——Mining exhibit 460
——Recording instrument exhibit 398
Pan-Americanism. Swiggett 513
Paper. Special for recording instruments, etc..... 193
Parks, F. E..... 878
Parmelee, H. C..... 575
Parrish, K. C..... 340
Patent Laws. Hearing of the proposed amendment 76
Patents. Electrochemical Digest..65, 131, 196, 268, 341, 403, 463, 575, 771, 931

Patents. Paint remover patent decision before Court of Appeals..... 350
Patent Office procedure..... 466
Patents. Recent chemical and metallurgical..63, 120, 185, 249, 391, 449, 504, 569, 641, 700, 762, 815, 871, 923
Patent reform suggestions..... 200
Patent suit procedure..... 405
Patent system. Needed changes..... 468
Peat. Distillation. Bartholomew. (P.) 817
Peat fuel..... 254
Peat. Production in 1914..... 846
Pennsylvania Steel Co. Gas blowing engines..... 516
Pensacola Tar & Turpentine Co..... 762
Perkin medal presented to Edward Weston. Photo..... 111
Perry, O. B..... 462
Petroleum. California yield in 1914.. 847
——Dehydration. Laird-Raney. (P.)... 570
——Emulsions treated by electricity. (P.)..... 122
——Estimation of aromatic hydrocarbons in. Rittman, Twomey and Egloff 682
——Industry of California..... 577
——Improvement of by aluminium chloride process. McAfee..... 592
Pfaudler Co. Exhibit..... 693
Phelps-Dodge properties. Leaching tests. Addicks..... 748
Phenol. Synthetic. Ney..... 686
Phillips, William B..... 520
Phosphorus. Removal from tungsten ores. Becket. (P.)..... 923
Photography. Physics of. Mees..... 923
Photomicrographic apparatus. Improved 928
Physics of the photographic process. Mees 923
Picric acid. Synthetic. Ney..... 686
Pierrefeu alain de..... 462
Pig breaker. Johnson..... 44
Pittsburgh-Dolores Mining Company.... 12

PLATING:
——Addition agents. Meurant. (D.)... 132
——Adjustment of electrode height. Chapman. (D.)..... 576
——Alloy of aluminium and gold. Linsenmayer. (D.)..... 197
——Alloy of nickel and aluminium. Frishmuth and Van Trouk. (D.)..... 197
——Alloy to resist tarnishing better than silver. Cowper, Coles, Altman. (D.)..... 268
——Aluminium. Corbelli, Jeancon, Williams, Collins. (D.)..... 341
——Aluminium. Hall. (P.)..... 570
——Aluminium deposition. Howard. (D.) 197
——Anodes. Digest of patents relating to.....403, 463, 575
——Anode frames. Bridgman. (D.)... 575
——Brass. Rust. (D.)..... 196
——Brass. Walenn. (D.)..... 196
——Brass on iron, steel, and other metals. Thomas. (D.)..... 268
——Carbons for arc lighting. Bush. (D.) 932
——Cleaning and plating in the same solution. Watts..... 327
——Cobalt. Kalmus..... 328
——Coatings of different thicknesses. Forbes. (D.)..... 771
Woodworth. (D.)..... 771
——Cobalt..... 840
——Copper on joints in incandescent lamp. Edison. (D.)..... 932
——Copper cyanide plating solutions. Weber..... 255
——Duplicating statuary. Barrie. (D.). 821
——Electric printing of designs on papers and fabrics. Friese-Greene. (D.) 66
——Frame for holding articles. Watrous. (D.)..... 771
——Hangers. Patent relating to....821, 932
——Interior of pipes. Parmelee. (D.) 772
——Magnetite coating on iron. Hollis. (D.)..... 65
——Manufacture of tubing. Wood. (D.) 821
——Mold production. Closson. (D.).. 821
——Ornamenting copper and iron. Bay. (D.)..... 196
——Plating wire-screen cloth. Burrows. (D.)..... 268
——Protection against reversal. Muller. (D.)..... 932
——Regulation of thickness of deposit. Bush. (D.)..... 772
——Silver. Campbell. (D.)..... 197
——Silver. Matthews. (D.)..... 771
——Surrounding frame for anodes. Van Winkle. (D.)..... 404
——Treatment of aluminium surfaces. Roux. (P.)..... 570
——Use of sulphurous acid. Tossizza. (D.)..... 132
——Zinc on iron and steel. Alexander. (D.)..... 268

PLATINUM:
——Boats for carbon determination by direct combustion. Siever 525
——Data on..... 64
——In Russia..... 254
——Newspaper chemistry..... 525
——Ore from Boss mine. Nevada.... 453
——Recovery in mint..... 16
——Refineries in Russia..... 585
Platinum. Osmium alloys. Zimmerman. (P.)..... 762
Platinum Mining and Milling Co..... 138
Plaut, Albert..... 575
Plumb, A. M..... 520
Plymouth Consolidated Mill. Palmer.. 617
Poidometer test..... 336
Polhemus, J. H..... 65
Porcelain ware. American made for chemical laboratories..... 461
Porcupine Crown Mines, Ltd.....208, 585
Porcupine district metallurgical practice. Cunningham. (S.)..... 187
Portland cement production in U. S. in 1914..... 586
Portland Gold Mining Co.....403, 745

POTASH:
——Feldspar as a source. Cushman and Coggeshall..... 99
——From mill tailings..... 918
——German and other sources of potash supply. MacDowell..... 179
——German potash syndicate..... 402
——Imports of salts..... 529
——Industry in Utah.....482, 526, 582
——In U. S. Rogers. (S.)..... 387
——Kelp..... 860
——Kelp industry in Scotland..... 443
——Manila Bay seaweed..... 586
——Situation. Beckman..... 582
——Situation. Clennell..... 760
——Situation. Dolbear..... 481
——Wood and plant ashes. Bradley.. 841
Potassium. Alltotropy of. Vosmaer.... 536
Potassium chlorate by electrolysis. Laib. (P.)..... 641
Potassium cyanide. Canadian imports.. 717
Potassium ferro and ferricyanides..... 717
Potential of the ferrocyanide. Ferrocyanide electrode. Schoch and Felsing. (S.)..... 568
Powdered coal plant at Anaconda.... 333
Powdered coal at Anaconda. Mathewson 728
Powdered coal. Burning in reverberatories. Browne..... 728
Powdered coal for firing reverberatory furnaces. Browne and Bender.. 182
Preparedness. Efficiency of in business. Calder..... 936
Primos Chemical Co..... 12
Printing. Electric of designs on paper fabrics. Friese-Greene. (D.).. 66
Producer gas. Kline..... 728
Producer gas. Important advance in efficiency..... 399
Producer. Gas and ammonia recovery plant. (British.) Lymn..... 456
Prospectors short course..... 403
Protecting polyphase motors against phase failure and reversal..... 703
Pulverizer mill. Fuller. Lehigh..... 904
Pump. Centrifugal. D'Olier..... 512
——Centrifugal..... 762
——Concrete..... 130
——Diaphragm for cyanide plants..... 455
Turbine vacuum and boiler feed..... 978
——Vacuum. Ingersoll-Rand..... 769
Pumping. Air lift. Berggreen. (S.)..392, 507
Purdue University. Course in high temperature measurements. Ferry 454
——Independent chemical engineering course. Peffer..... 826
Pyritic smelting at Mount Lyell..... 116
Pyrometers. Multiple-type recording instrument for pyrometers..... 643
——Tapalog-multiple recording.....260, 918
Pyrometry. Recent progress. Darling.. 443
Pyrophoric alloy suit.....135, 145

Q

QUARTZ MERCURY. Vapor lamp. Maily..... 55
Quebec. Mineral resources..... 890
Quicksilver production..... 18

R

RADIATED HEAT. Money value of... 279
Radium in 1914..... 146
Radium production by Bureau of Mines 475, 965
Radium situation. Bleecker.....143, 202
Rail tests report..... 846
Rand metallurgy. Bosquie. (S.)..... 925
Raritan Copper Works. Exhibit..... 693
Ray Consolidated Copper Co....16, 140, 527
Reaction velocity in viscous media. Callow..... 500
Refractometer. Abbe. Shook..... 21
Refractometer. Telfrich. Shook..... 19
Refractories of the Rocky Mountain region and some of their products. Bailar..... 257
Refractory materials and the war (London)..... 254
Rennerfelt electric furnace..... 702
Research and chemical industry. Forster 544
——American Chemical Society.....885, 941
——Burgess, Bacon, Comey, Fink, Cushman, Herreshoff, Bogert..... 921
Research in technology. Carpenter 545
Research Corporation. Exhibit..... 693
Resistance and inductance of wires.... 860
Resistance standards. Mercurial..... 717
Resistivities. Electric at high temperatures. Hering.....23, 70, 202
Resources and possibilities of chemical industry in the Southwest. Baruch..... 604
Richards, Jos. W. Photo.....709, 771
Richards, Robt. H..... 196
Richards, Theodore W. Nobel prize.... 884
Richardson-Phoenix Co..... 918
Ricketts & Co..... 267
Riker, Andrew L..... 708
Riley, Lewis A., 2nd..... 646
Road treatment. Use of refined tars. Sharples..... 918
Roasting. Formation and decomposition of sulphates. Dudley.....221, 303
Roasting and leaching, concentration slimes tailings. Addicks..... 531
Roberts, James Coles..... 878
Roberts, J. F. Mitchell..... 340
Robesonia furnace. Reducing sulphur content..... 701
Robins, Thomas..... 708
Rochelle salt (Tartaric acid) manufacture. Best..... 613
Rockwell, J. J..... 820
Roessler & Hasslacher Co.....13, 890
Roots, P. H. & F. M..... 745
Rosengarten, George D. Photo..... 41
Rubber. Testing of rubber goods..... 792
Rubey, H. M..... 575
Russell, William..... 340
Russia. Nitrogen fixation in..... 828
Russia. Rewards for methods of utilizing alcohol..... 352
Ryan, John D..... 131

S

SACKETT, B. L..... 402
Safety and sanitation..... 177
Safety First at Colorado Fuel and Iron Co. 234
Sagert, Charles..... 771
Salida smelter. Lead smelting. Weeks. (S.)..... 814
Salt. Canadian industry..... 846
Saltpetre (see Chile nitrate)
Sampling lead bullion..... 930
Sanitary conditions studied by Bureau of Mines..... 577
Sarco Engineering Co..... 340
Sargent Co., E. H..... 745
Saunders, William L. (Photo.)..... 709
Sauveur photomicrographic apparatus.... 928
Scale. Removed by pickling. Hering.... 785
Scarcity of steel..... 647
Schaeffer & Budenberg Mfg. Co.....338, 695
Schaum & Uhlinger. Exhibit..... 695
Scheelite. Method of treating. Becket. (P.)..... 923
Schmalz, Charles H..... 462
School of Chemistry of Univ. of Pittsburgh..... 782
Schutte & Koerting Co..... 695
——Bihn-Jones air lift..... 876
Scientific Specialties Company..... 64
Scott, Arthur Putnam..... 462
Scott & Co., E. Exhibit..... 695
Scottish oil trade..... 254
Sea Call. Failure of..... 884
Seamless hollow spheres. Patton. (D.).. 132
See, Howard..... 341
Selby Smelter Smoke Commission. Findings..... 29
Sellers, Mathew B..... 708
Selmi, L..... 878
Sentinel pyrometers and paste..... 192
Sewage disposal. New electrolytic method. Olsen.....530, 735, 793
Sewage. Treatment by aeration in presence of activated sludge. Bartow. 901
Sewer pipe and drain tile-experiments.... 729
Sharples Specialty Co. Exhibit..... 695
Sheffield exhibition of German cutlery.... 370
Sherman, F. W..... 520
Shipping concentrates. Parcel post ruling. 526
Sidio fused silica ware..... 875
Silica brick. For the byproduct coke oven. Seaver..... 861
Silica dishes for sulphuric acid concentration. Marshall..... 136
Silica graphite paint..... 481
Silicium dioxyde fused silica glassware.. 875
Silver. See also Gold and Silver.
Silver. Decline in price..... 526
Silver nugget weighing 2600 pounds..... 341
Silver sidewalk..... 890
Simonds Mfg. Co..... 832
Simpson, K. M..... 131
Skinner, Thomas M., Jr.....341, 821
Slags, Basic open-hearth, The action of fluorspar. Hamilton..... 8
Slag. Utilization of heat from..... 573
Slime agitation and solution replacement methods at West End Mill, Tonopah, Nev. Carpenter..... 671
Slime cyanidation. Development of continuous counter-current decantation. Pentland..... 105
Slime residue. Determining dissolved gold. (S.)..... 119
Smelters. Equipment in Arizona..... 904
Smelters. Federal investigation..... 274
Smelter smoke commission. Selby findings..... 29
Smelting furnaces. Copper. Canada.... 15
Smelting. Lead. High-lime slags. Bretherton. (S.)..... 766

Smelting. Pyritic smelting at Mount Lyell 116
Smith, Acheson 821, 931
Smith, I. C..... 745
Smoke abatement. Flourishing German society. Kershaw 261
Atmospheric pollution in towns. Kershaw 967
Smoke. Electrical precipitation..... 160
Smoke. Facts and treatment. Fulton... 226
Smoke litigation in California..... 206
Smoke nuisance. Solution of by electrical precipitation. Bradley..697, 911
Snelling, Walter O..... 931
Snyder Electric Furnace Co....185, 336, 586
Soaking Pit. Electric furnace for. Barty 560
Soapstone production 717
Society of Chemical Industry..... 782
——Manchester meeting 543
——N. Y. Section. Dyestuff situation. (Chandler, Pratt, Schoellkopf, Norton, Childs, Matthews, Wood, Alden, Nichols, Reese, Beckers, Metz, Bogert.) 779
——N. Y. Section..... 921
Sodium. Electric furnace manufacture. Acker. (P.)..... 764
Sodium chloride. Electrolysis.
——Allen. (P.)..... 815
——Allotropy. Vosmaer 954
——Nelson. (P.)..... 815
——Jenkins. (P.)..... 815
——Jewell. (P.)..... 506
Sodium cyanide. Canadian imports..... 717
Sodium cyanide. Production..... 13
Sodium hydrate. See Caustic Soda.
Sodium perborate. Arndt 965
Sons of Gwalia, Australia. Cyaniding. Wauchope. (S.) 925
South American Handbook..... 671
South American trade. Co-operation in chemical export 476
Southern Aluminium Co..... 832
Southwest. Resources and possibilities of chemical industry. Baruch..... 604
Sowers Manufacturing Co. Exhibit..... 695
Specific gravity. Thermostat for. Browning and Symons..... 500
Specific heat and fusion of ice..... 762
Specific heat of liquids. Determination of. Hartung 500
Spencer Lens Co..... 745
Sperry, Elmer A. (Photo.)..... 708
Sprague, Frank Julian..... 708
Sprays for cooling water..... 401
Squires, H. B..... 745
St. Croix Paper Co..... 770
Stamford Manufacturing Co. Exhibit... 695
Stamp Mills. Cam for. (S.) 118
Standards. Mercurial Resistance..... 717
Standard boiler specifications of A. S. M. E. 240
Standard Chemical Co. Bleeker..... 143
Standardization of acid solutions. Randall and Scalione 787
Stark Rolling Mill Co..... 792
Statement on change to semi-monthly by James H. McGraw..... 521
Stavanger Electrostaalverk..... 64
Staver, W. H..... 575
Stearic acid 742
Steel. See Iron and Steel.....
Steinmetz, Chas. P..... 931
Stephens-Adamson Mfg. Co..... 717
Sticht, Robert C..... 341
Stokers. Hazan Underfeed..... 64
Storage batteries. Lead poisoning in manufacture 347
Stoughton, Bradley..... 402
Stratification process of copper refining. Pyne and Green. (P.)..... 816
——Pyne 895
Stratton's Independence, Ltd....13, 150, 585
——Sale 416
Streich, G. F..... 462
Sugar. Vapor pressure of concentrated solutions. Wood 499
Sugar extraction by electricity. Schwerin. (D.) 131
Sugar house evaporating apparatus. Kerr. (S.) 506
Sullivan Machinery Co. Air-lift pump... 392
Sulman, H. L..... 575
Sulphur. Methods of determining..... 586
——Recovery from smelting furnaces. Lamoreaux-Renwick-Hall. (P.).. 452
——"Vesuvius" Burner. 453
Sulphuric Acid:
——Concentration. Capsule apparatus for. Mason 17
——Concentration in silica dishes. Marshall 136
——Contact process. Brockbank. (P.).. 971
——Electrolysis. Jeffery 964
——New agricultural use for..... 648
Sulphurous acid from fumes. Removal. Bergmann and Berliner. (S.).. 62
Superor Chemical Corporation..... 586
Surface combustion. Lucke..... 729
Swart, W. G..... 131, 196
Sweet, John Edson, receives John Fritz Medal 75
Sweetland Filter Press Co. Exhibit..... 695
Swenson Evaporator Co..... 695, 832
Synopsis of recent chemical and metallurgical literature...61, 118, 187, 330, 387, 446, 506, 566, 638, 764 873, 924
Synthetic fuel oil. Snelling..... 180

T

Tailings for road materials 16
Talc production in 1914 717
Tapalog. A new multiple record pyrometer 260, 918
Tariff question. Gross 676
Tariff. Necessity of reform for American chemical industries 676
Tariff. Possibility of extra session of Congress 476
Tariff reform for chemical manufacturer. 705
Tars. Development for use on roads Sharples 918
Tartaric acid manufacture. Best 613
Taylor Instrument Companies 745
Technical and scientific attaches 502
Telephony. The debt of transcontinental telephony to metallurgy 67
Temperature measurement under rapidly changing conditions. Peterson. (S.) 189
Temperate scale. Holborn. 966
Tennessee Copper Co.....275, 276
Tenicnte Topics 701
Tennessee Power Co. Exhibit 695
Testing of materials 425
Texas. Mineral resources 840
Tharp, W. C..... 462
Thayer, B. B.....131, 341
Photo 709
Thermal conductivity of refractories. Dudley 315
Thermal principles of the blast furnace. Johnson 718, 787, 833, 905
Thermit welding of camshafts 929
Thermo-couples. Fuller 319
Thermostat for specific gravity determinations. Browning and Symons 500
Thickeners. Dorr 91
Thickener. Automatic regulation of. Dorr. (P.) 452
Thickeners. Door. At Nevada Consolidated 716
Thompson, M. R..... 131
Thorium 735
——Atomic weight. Hönigschmid 966
Thum, E. E..... 341
Thurston, W. R..... 931
Thwing Instrument Co. Exhibit 695
Ticka, L. T..... 267
Timber Butte Mill concentration. Simons. (S.) 189, 447
Tin boiler plugs. Investigation. Burgess and De Merica 568
——Burgess 712
Tin:
——Concentrating mill in Transvaal.... 16
——Electrolytic refining. Michaud and Delasson. (P.) 187
——Exports from Bolivia in 1914 402
——Exports from Federated Malay States 150
——In Nevada 220
——Output of the Federated Malay States in 1914 403
——Price fluctuations 706
Tintic Milling Co..... 889
Titan bronze 400, 645
Titanium Alloy Mfg. Co.....747, 846
Titanium. Alloys for iron and steel baths. Goldschmidt and Weil. (P.) 641
——In steel. Fitz Gerald..... 936
Titanium-aluminium bronze castings. Corse 511
Titanium. Influence on steel. Fitzgerald 28
Titanium. Geology of Virginia deposits 573
Titus, C. C..... 131
Toch Brothers. Exhibit 695
Tolhurst Machine Works. Exhibit 695
Toluol from California oils..... 828
Tonopah Belmont Development Co..... 417
Tonopah Mining Co..... 416
Tonopah plant of the Belmont Milling Co. Jones. (S.)..... 811
Transcontinental telephony 67
Transformers for electric furnace work 776
Transvaal gold production..15, 425, 529, 704, 745
Trent agitator at West End mill. Carpenter 671
Trethewey Silver Cobalt Mines, Ltd.... 207
Tripoli compositions 742
Troegerlith Tile Co. Exhibit 695
Tropenas Converter Co.....585, 586
Tropical agriculture 291
Tube lamps. Moore 55
Tube milling in all-slime cyanide process. Pentland 204
Tube milling. Closed circuit. Pentland 826
Tube milling for the flotation or oil-concentration process. Easton 89
Tube milling. Injector for tube-mill feed. Carless. (S.) 389
Tube-mills. Scoop discharges. Dowling. (S.) 874
Tube-milling tonnage calculation and notes on tube-milling. Cunningham 22
——Haynes 10
——Lowden 70
——Cunningham 138
Tungsten:
——Burma. Principal producing country 366
——Concentrates. Price of 577
——Preparation for lamp filaments. Gmür-Zehnder. (P.) 924
Tungsten (Continued.)
——Production of tungsten powder. Parsgrund (P.) 250
——Treatment of tungsten ores. Becket. (P.) 923
Tuttle, H. E..... 267
Tyler, W. S., Co. 745

U

Udden, J. A..... 979
Ulcoloy 378
Ultraviolet rays 586
Union Oil Co..... 745
Union Sulphur Co. Exhibit 695
United Engineering Societies library service bureau 366
United Gas Improvement Co. Exhibit.. 695
United Lead Co. Exhibit 695
Units. Saving trouble in handling 824
Units. Standardization of metallurgical 828
Unstable states in arc and glow. Cady 866
U. S. Blow Pipe and Dust Collecting Co. 453
U. S. Geological Survey. Nevada's mineral production 15
U. S. Government exhibits..... 695
U. S. Smelting, Refining & Mining Co. Exhibit 695
U. S. Smelting, Refining & Mining Co.. 274
United States Steel Corporation. Operations in 1914 201
University and industry. American Chemical Society 885, 941
University of Nevada 12
University of Pittsburgh. School of chemistry 782
Uranium in 1914 146
Uranium for carnotite..... 965
Utah Copper Co.....140, 527
Utah Iron & Steel Co..... 890
Utah. Low grade and complex ores. Metallurgy 472
Utley. Howard H..... 931

V

Vacuum Pans, Kerr 485
Vacuum pump. (Ingersoll-Rand) 769
——Nash 978
Vacuum tubes. Moore 55
Valley Iron Works. Exhibit 695
Vanadium in 1914..... 146
Vanadium. Alumino-vanadium. Clark.. 712
Vanadium from carnotite..... 965
Vanadium from oxide to steel. Bleecker and Morrison 492
Van Winkle, Abraham 931
Vapor pressures and specific volumes of mixtures of volatile with non-volatile liquids 499
Vapor pressure of concentrated sugar solutions. Wood 499
Ventilation. Use of ozone..... 975
Vesuvius sulphur burner 453
Vindicator Consolidated mill concentration at 142
Viscosimeters. MacMichael 767
Vitreosil for sulphuric acid concentration. Marshall 136
Voelker, Dr. A..... 875
Vom Baur, C. H..... 979
Vulcanized fibre. Almy 746

W

Wagner, Fred H..... 979
Ward & Sons, Fred..... 745
Ware, H. S..... 131
Water. Barnstead distilling apparatus.. 704
Waterpower in the Northwest. Benson 591
Water treatment for boilers. Haythorpe. (P.) 506
Ways of the chemists 343
Webster, Arthur G..... 708
Weed, Walter Harvey 65
Wedge. Utley 745
Weidleins copper process 652
Weight correction on metal blanks for coins. Johnson. (D.)..... 131
Welding aluminium. Autogenous method. Pannell 712
Welding camshafts. Thermit..... 929
Welding. Oxy-acetylene. (Prest-O-Lite.) 770
Welding. Scrap nickel anodes 453
Welfare work in mining and metallurgy 134
Wellington Mines Co..... 139
West, Thomas Dyson 462
West End Mill. Tonopah, Nev. Carpenter 671
Western Metallurgical Field..12, 73, 138, 206, 273, 348, 415, 471, 526, 651, 887
Western Precipitation Co..... 745
Western Spring & Axle Co..... 877
Westinghouse Electric & Mfg. Co.... 745
Westinghouse air ozonator..... 975
Westinghouse oil drying outfit..... 977
Weston, Edward, receives Perkin medal. Photo 111
Weston instruments. New 819
What the chemical industry has a right to expect from the American nation 647
Whitaker, Orvil R..... 575
Whitley, C. W..... 821

Whitney, W. R., Photo 709
Wiggin, A. E. 462
Wilfley table-standard riffles 577
Wilfley tables. New riffling 819
Williams, R. G. 878
Williams Apparatus Co 967
Williamson, F. O. 878
Wilson-Maulen Co. Exhibit 695
Witherill, C. S. 131
Wolverine Copper Mining Co 140
Wood, Henry A. W. 708
Wood alcohol from hardwood distillation. French and Withrow 30
Withrow 797
Woodward, Robert S. 708
Woodworth, S. E. 878
Workmen's compensation insurance in Colorado 472
Wraith, C. R. 462

X

X-Ray examination of metals. Davey. (S.) 189

Y

Yamashita, M. 820
Yarnall-Waring Co 918
Yeatman, Pope 402
Young, A. B. 402
Water meter. The Yarnall-Waring Co. 392

Z

Zaremba Co. Exhibit 695
Zeller, H. P. 771, 931
Zelnicker Supply Co., W. A. 585
Zinc:
——Allotropy. Vosmaer 954
——Anaconda may enter field 526
——A spectacular spelter market 199
——Briquet for use in zinc furnaces. Brooks. (P.) 451
——British Columbia 888
——Canadian bounty on 887
——Complex ore problem. Motherwell 8
——Complex ore smelting. Hyde. (P.) 63
——Concentration at the Timber Butte Mill. Simons. (S.) 189
——Development of zinc smelting in U. S. Stone 726
——Economics of zinc metallurgy. Ingalls 725
——Effect of enhanced value on silver 526
——Effect of prices on cyanidation 406
——Electric furnace production. Highfield. (P.) 817
——Electric zinc smelting improvement. Johnson. (P.) 504
——Electric zinc furnace. (P.) 122
——Electrolytic 774
——Exports 12
——Flotation treatment of Elm Orlu zinc ore. Simons. (P.) 447
——French process. Electrolytic 888
Zinc: (Continued.)
——High grade spelter not as valuable as diamonds 935
——Influence of impurities on. Rigg and Morse 712
——Magnetic separation of zinc-iron sulphide ores 572
——Marked activity in the Joplin district 348
——Mill tailings for road materials 16
——New smelting plants 529
——Output in New Jersey in 1914 586
——Precipitation tests. Herz. (S.) 973
——Prevention of blue powder in electric furnace. Johnson. (P.) .. 763
——Price changes 706
——Progress in 1914 6
——Recovery of zinc from waste liquors. (P.) 122
——Removal of cadmium from zinc ores. Rigg. (P.) 250
——Roasting zinc ores. Simonds. (P.) 505
——Separation from lead by flotation. (S.) 874
——Smelting at Pittsburg, Kansas 274
——Spelter and other coating metals .. 345
Zinc-bronze. Standard test specimens. Rawdon 712
Zinc-lime ore leaching with acids. Ralston and Gartside 151
Zinc oxide. From lead blast furnace slag, South Chicago. Pulsifer 783
Zinc oxide. Production from low-grade carbonate ore at Leadville 631
Zirconia. Notes on refractory properties. Meyer 263
Zirconium. Iron alloy for lamp filaments. Brown. (P.) 924

AUTHORS' INDEX

ADDICKS, LAWRENCE. Roasting and leaching concentrator slimes tailings 531
——The electrolysis of copper sulphate liquors using carbon anodes 748
Aitchison, Leslie. Experiments on the influence of composition upon the corrosion of steel 501
Allen, Glenn L., and George Belchic. Flotation of Joplin-Galena slimes 847
Almy, Charles, Jr. Vulcanized fibre 746
Anderson, J. S. An electromagnetic vacuum balance 500
Armstrong, Henry E. Development and control of industry by public influence 544
Ash, Charles S. Contribution of the chemist to the California wine industry 283
Austin, W. L. Leaching of copper ores 662

BACON, RAYMOND F. Copper leaching 327
——Administration of industrial research laboratories 922
Baekeland, L. H. Applied chemistry .. 677
——Edward Weston's inventions 112
——Naval Consulting Board 943
——Statement at hearing on proposed amendment of patent laws 77
Bailar, J. C. Refractories of the Rocky Mountain region and some of their products 257
Bailey, Gregory T., and R. H. Walton. Separation of white metal and gunmetal borings 204
Baily, T. F. Electric furnace for reheating, heat treating and annealing 558
Bancroft, Wilder D. Neutralization of absorbed ions 318
——Coagulation of albumin by electrolyte 317
Barnes, E. J., and A. McWilliams. Brinell hardness and tenacity factors of a series of heat treated special steels 502
Barnes, H. B. Industrial motor applications 297
Bartow, Edward. Treatment of sewage by aeration in the presence of activated sludge 901
Baruch, Edgar. Resources and possibilities of chemical industry in the Southwest 604
Beckett, J. S. Examination of firebricks 136
Beckman, J. W. The potash situation .. 582
Bedford, E. T. Contributions of the chemist to the corn products industry 283
Beilby, G. T. Hardening and overstrain in metals 173
——Chemical engineering 545
Belchic, George, and Allen, Glenn L. Flotation of Joplin galena slimes 847
Bell, Norman Murray. On the anodic solution of lead 500
Bender, Louis V. Coal-dust fired reverberatories at the Washoe Reduction Works 184
Benson, H. K. The industrial resources and opportunities of the North west 589
Bentley, R. I. Contributions of the chemist to the preserved foods industry 286
Berman, Harry C., and Francis C. Frary. Electrolytic preparation of magnesium 324
Best, Otto. Manufacture of cream tartar 613
Betts, Anson G. Electrolytic antimony refining 848
Bleecker, Warren F., and Walter L. Morrison. Vanadium from oxide to steel 492
Bleecker, Warren F. The radium situation 143, 202
Blyth, W. B. Flotation in gold metallurgy 308
Bradley, G. O. A coarse crushing plant of 1000 tons capacity 721
Bradley, Harlow. Potash from wood and plant ashes 841
Bradley, Linn. Cottrell process of electrical precipitation 697
——Solution of smoke, fume and dust problems by electrical precipitation 911
Brickerstein, Townsend and Byrnes. Digest of electrochemical U. S. patents..65, 131, 196, 268, 341, 403, 463, 575, 771
Brown, Everard. The purification of boiler feed water 156
Brown, G. S. Contributions of the chemist to the cement industy 284
Browne, David H. Coal-dust fired reverberatory furnaces at Copper Cliff 181
——Burning pulverized coal in reverberatory furnaces 728
Browning, K. C., and C. T. Symons. A convenient thermostat for accurate specific gravity determinations and a gas pressure regulator 500
Buck, Daniel M. Recent progress in corrosion resistance 420
Burgess, C. F. Research in chemical industry 921
Burgess, George K., and R. A. Hadfield. Sound steel ingots and rails .. 178
——Sound steel ingots and rails 445
Burgess, G. K. Investigation of fusible tin boiler plugs 712
Burman, Birger F. Efficiency of the blast furnace operation 624
Butler, Nicholas Murray. Co-operation between university and industry 886
Byrnes, Brickenstein and Townsend. Digest of electrochemical U. S. patents..65, 131, 196, 268, 341, 403, 463, 575, 771

CADY, W. G. Unstable states in arc and glow 866
Calder, John. Efficiency of preparedness in business 936
Calhane, D. F. Electro-analysis of nickel 8
Callow, R. H. Reaction velocity in viscous media 500
Campbell, F. H. The vapor pressures and specific volumes of binary mixtures of volatile with non-volatile liquids 499
Campbell, William. The metallography of copper 721
Canby, R. C. Copper leaching 323
Cantley, C. L. Coal and iron in Nova Scotia and Newfoundland 887
Carpenter, Charles C. Research in technology 545
Carpenter, E. E. Cyanide practice at Churchill Milling Co 813
Carpenter, Jay A. Slime agitation and solution and replacement methods at the West End mill, Tonopah, Nev. 671
Chandler, Chas. F. Speech of presentation of Perkin medal to Edward Weston 111
——Dyestuff situation 779
Channing, J. Parke. Copper leaching ... 323
Clark, A. C. Electrolytic copper refining 661
Clark, William W. The determination of manganese in ferrovanadium 155
——Use of alumino-vanadium 712
Clennell, J. E. Recent advances in the manufacture of cyanagen compounds 756
Clevenger, G. H. Precipitation of cyanide solutions 725, 803, 852
Clevenger, G. H., and Wells, A. E. The Co-operative metallurgical exhibit at the Panama-Pacific International Exposition 743
Coggeshall, George W., and Allerton S. Cushman. Feldspar as a possible source of American potash 99
Collins, George E. Britannia linings for Hardinge mills 650
Comstock, George F. Alumina in steel 891
Cornell, Sidney. The open-hearth versus the electric furnace in the manufacture of commercial steels 630
Corse, W. M. Titanium-aluminium bronze castings 511
——Aluminium-bronze alloys 712
Crocker, Ernest C., and M. deKay Thompson. LeClanche cells 319
Cunningham, Noel. Tube-mill tonnage calculation 22, 138
Cushman, Allerton S., and George W. Coggeshall. Feldspar as a possible source of American potash 99

DARLING, C. R. Recent progress in pyrometry 443
Darrah, W. A. Electric arc in vapors and gases at reduced pressures 915
Desch, Cecil H. Crystal twinning and the martensitic structure 174
Dittus, Edward J. The effect of high ignition voltages on the accuracy of bomb calorimeter determinations 480
Dolbear, Samuel H. The potash situation 481
———Current status of the borax industry 564
Dorr, John V. N. The use of hydrometallurgical apparatus in chemical engineering 91
Douglas, James. Copper metallurgy of the Southwest 658
Dudley, Boyd, Jr. Thermal conductivity refractories 315
———The chloridizing roast and its application to the separation of copper from nickel 181
———The Formation and decomposition of sulphates during roasting 22, 303
du Rell. C. Terry. Liquid jets 714

EASTER, H. F. Lead smelting at El Paso 814
Easton, W. B. Tube-milling for the flotation or oil concentration process 89
Edwards, C. A. Hardening of metals by quenching 174
Egloff, G., Ritmann, W. F., and Twomey, T. J. The estimation of aromatic hydrocarbons in cracked petroleum 682
Emerson, Harrington. Efficiency in our natural resources 697
Evans, E. V. Removal of carbon bisulphide from coal-gas 239

FERRY, ERVIN S. The course in high temperature measurements at Purdue University 454
Fink, Colin G. The electrochemical production of organic compounds.. 211
Finlay, J. R. Industrial energy as a military weapon 547
Fitz Gerald, Fr. A. J. Has titanium any influence on the properties of steel? 28
———What metallography can show..... 936
Fleming, A. P. Engineering training... 371
Flinn, A. D. Experience with brass in civil engineering work..... 712
Flynn, F. N. and Roger H. Hatchett. Solution control in ferric-chloride leaching of sulphide copper ores. 291
Forbes, G. S. Electrolysis of aromatic compounds 212
Forster, M. O. Research and chemical industry 544
Frankland, Percy F. The chemical industries of Germany..... 379
Franklin, W. S. Analogies between electricity and mechanics..... 317
Frary, Francis C. and Harry C. Berman. Electrolytic preparation of magnesium 324
French, Edward H. and James R. Withrow. The hardwood distillation industry in America..... 30
Frink, Robert L. Glass industry..... 800
Fuller, T. S. Thermo-couples..... 319

GAHL, RUDOLF. Flotation results.. 408
Gartside, A. E. and O. C. Ralston. Leaching a zinc-lime ore with acids. 151
Gathmann, Emil. Methods of preventing piping in steel ingots..... 656
Gies, W. J. Co-operation between university and industry..... 886
Gillett, H. W. Melting aluminium chips. 712
Giolitti, F. Recent progress and present state of the technical application of the case hardening of steel.. 656
Gosrow, R. C. Electric furnace in the foundry 882
Gray, James H. Steel making in the electric furnace 656
Greiner, Adolphe. The heating of an open-hearth furnace by means of tar. 445
Grenfell, D. S., and O. L. Kowalke. Reaction between graphite and magnesia 316
Gross, Howard H. Tariff question..... 700

HADFIELD, ROBERT A., and George K. Burgess. Sound steel ingots and rails 445
———Sound steel ingots and rails..... 178
Hadfield, Robert. Hardening of metals.. 173
Hall, E. J. Bottle filling alarm..... 347
Hall, John Howe. Iron and steel castings 655
Hamilton, W. S. The action of fluorspar on basic open-hearth slags.. 8
Hamor, W. A. The dedication of the new building of the Mellon Institute 266
Hanna, W. C. The Fleming dust collecting system 609
Harden, Joh. Carbon bricks for blast furnaces 202
Harlow, F. J., and R. S. Willows. A simple method of deriving the Gibbs adsorption formula..... 499
Harper, C. H., Herbert T. Kalmus, and W. L. Lavell. Electroplating with cobalt 328
Harrington, R. E. Lighting of electrolytic tank rooms 327
Hartung, E. J. A new method for determining the specific heats of liquids 500
Hatchett, Roger H., and F. N. Flynn. Solution control in ferric-chloride leaching of sulphide copper ores 291
Hayward, Carl R. Physical properties of copper 661
Hazard, F. R. Contributions of the chemist to the soda industry.... 285
Haynes, Justin H. Tube milling tonnage calculation and notes on tube-milling 10
Heckel, G. B. Paint 807
Henderson, G. G. Presidential address. (Soc. of Chem. Ind.)..... 543
Hering, Carl. Comparison of electric resistivities at high temperature. 23, 70, 202
———Some of Edward Weston's achievements in the field of electricity. 115
———Removing iron scale by pickling.. 785
Herreshoff, J. B. Francis. Contributions of the chemist to the copper industry 283
Herty, Charles H. Co-operation in matters chemical 588
Hesse, Bernhard C. The contributions of the chemist to the industrial development of the United States. 287
Heynemann, L. Make your mistakes on a small scale..... 936
Hibbard, Henry D. The danger of throwing inventions open to the public 206
Hibbert, Harold. Electrolytic preparation of organic compounds..... 211
Hobbs, Franklin W. Contributions of the chemist to the textile industry 284
Hofman, H. O. The action of fluorspar on basic open-hearth slags. 136
———The smelting and refining of lead. 727
Honda, Kotaro. The nature of the A_2 transformation in iron..... 503
Horne, W. D. Contributions of the chemist to the sugar industry.. 284
Houghton, A. A. Contributions of the chemist to the glass industry.. 286
Howard, L. O. The new mill of the Daly West Mining Co., Park City, Utah 597
———Progress in copper metallurgy in the Globe district, Arizona..... 659
Howe, Henry M. Hardening with and without Martensitization 175
Humfrey, J. C. W. The amorphous phase in the hardening of steel.. 174

INGALLS, W. R. Speech at Cottrell dinner 83
———Some main points in the economics of the metallurgy of zinc..... 725
Ives, Herbert E. The illuminating engineer and ideal light..... 327

JENNINGS, WM. W. Carbon determination by the combustion method 70
Johnson, Charles Morris. An electric muffle furnace for the determination of carbon and oxygen in steel and tungsten powder..... 17
Johnson, J. E., Jr. Blast furnace plant auxiliaries and general arrangement. 373, 429, 495
———Chemical principles of the blast furnace 537, 634
———Filling the blast furnace.....161, 227
———Handling iron and cinder at the blast furnace 43, 85
———Possible applications of oxygen in metallurgy 483
———Thermal principles of the blast furnace 718, 787, 833, 905
Jones, A. H. Tube-milling tonnage calculation and notes on tube-milling 71
Jones, A. H. Cyanide practice at Tonopah 811

KALMUS, HERBERT T., C. H. Harper, and W. L. Lavell. Electroplating with cobalt..... 328
Kauffman, Edmund J. Adjustment of the direct electric lighting current to electro-analysis..... 524
Keeney, Robert M. Cyanide plant of Baker Mines Co. 947
Keffer, Robt., and Francis A. Thomson. The relative efficiency of various amalgams in the recovery of gold 367
Keough, Frederic W. Accident prevention in the chemical industries. 731
Kerr, E. W. Vacuum pans..... 485
———Condensers for evaporating apparatus 551
Kershaw, John B. C. Fuel-supply contracts and the progress of more scientific methods of purchase and control in America and Europe. 393
———A flourishing German smoke abatement society 261
———Atmospheric pollution of towns.... 970
Kline, Z. C. Gas producer development. 728
Kondo, R. Metallurgy of copper in Japan 658
Kowalke, O. L., and D. S. Grenfell. Reaction between graphite and magnesia 316
Kranz, William G. Electric furnace in the foundry 565
Kuryla, M. H., and L. D. Mills. Crushing and grinding 721
Kuryla, M. H. Solution of gold and silver 723

LAIST, FREDERICK. Advance in copper smelting 658
Lake, E. F. Limitations of the electric furnace in the manufacture of steel castings 137
Lamb, Richard. Copper leaching..... 324
Landis, W. S. The fixation of atmospheric nitrogen 213
Langmuir, Irving. Chemical reactions at low pressures 244
Lavell, W. L., Herbert T. Kalmus and C. H. Harper. Electroplating with cobalt 328
Lee, R. H. Wet ores in charcoal blast furnaces 882
Leisk, R. D. Hydrometallurgical treatment of Michigan copper tailings 233
Lever, William. Co-partnership in chemical industries 543
Lewis, W. K. Chemistry of amorphous solids 921
Lidbury, F. Austin. The American Electrochemical Society in its external relations 277
———The commercial aspects of organic electrochemistry 211
———Speech at Cottrell dinner..... 82
Lines, F. F. Duplex process of steel manufacture 656
Little, Arthur D. The industrial resources and opportunities of the South 281
———University and industry..... 941
Lloyd, Stewart J. The radium situation. 202
Lowden, H. B. Tube-milling tonnage calculation and notes on tube-milling 70
Lowry, T. M., and R. G. Parker. Metallic tilings 175
Lowry, T. Martin. The hardness of solid solutions 174
Lucke, C. E. Surface combustion..... 729
———Co-operation between university and industry 886
Lutts, Carlton G. Rapid analysis of bearing metals and high-copper content alloys 346

McAFEE, A. M. The improvement of high boiling petroleum oils, and the manufacture of gasoline as a by-product therefrom, by the action of aluminium chloride.... 592
McChance, Andrew. Interstrain theory of hardening 174
McKinney, Asa, and Frank C. Mathers. Electrolytic lead deposits..... 328
McWilliam, A., and E. J. Barnes. Brinell hardness and tenacity factors of a series of heat treated special steels 502
Macdowell, Charles H. German and other sources of potash..... 179
Maclaurin, R. C. University and industry 941
MacMichael, R. F. Viscosimeters..... 767
Maily, R. D. The quartz mercury-vapor lamp 55
Malm, Walter R. High temperature experimental furnace 70
Marshall, Albert E. Fused silica dishes for the concentration of sulphuric acid 136
Mason, Sidney. Contributions of the chemist to incandescent gas-mantle industry 284

Mason, William. The extraction of carbolic acid from oils of the distillation of coal tar..... 293
———Apparatus for the concentration of sulphuric acid 17
Mason, Wm. P. Contributions of the chemist to the potable water industry 286
Mathers, Frank C., and Asa McKinney. Electrolytic lead deposits..... 328
Mathesius, Walther. High blast heats in Mesaba practice 177
Mathewson, E. P. Present tendencies in copper metallurgy 141
———Anaconda practice in burning pulverized coal 728
Matthews, J. Merritt. Common sense on the dyestuff question..... 781
Meade, Richard K. The reburning of lime from alkali waste and other forms of precipitated carbonate of lime 289
Mees, C. E. K. Physics of the photographic process 923
Merica, P. D. Failure of structural brass 712
Meyer, H. Conrad. Further notes on the refractory properties of zirconia. 263
Mills, L. D. Filtration of slime..... 724
Mills, L. D., and Kuryla, M. H. Crushing and grinding..... 721
Miner, H. S. Chemistry of the incandescent gas mantle..... 50
Moore, D. McFarlan. Gaseous electric illumination 55
———Gaseous conductor light..... 885
Moore, F. L. Contributions of the chemist to the pulp and paper industry.. 287
Moore, R. J., and W. F. Rittman. The range of applicability of the liquid sulphur dioxide method for determining aromatic constituents in hydrocarbon mixtures 713
Moore, William C. Flaming arc carbons. 327
———Chemistry of flaming arc carbons... 52
Morrison, Walter L., and Warren F. Bleecker. Vanadium from oxide to steel 492
Morse, Henry C., and Rigg, Gilbert. Influences of impurities in spelter 712
Motherwell, W. Is there a complex-ore problem? 8
Muntz, G. Limitations of the electric furnace in the manufacture of steel castings 108
Mutscheller, A. The action of certain colloids on ions during electrolysis 353
———The relative migration velocity of the ions in complex electrolytes. 439

NEWTON, F. C. Desilverization of lead 181
Ney, A. H. Synthetic phenol and picric acid 686
Norris, George L. Steel alloys.....656, 739
Northrup, Edwin F. A classification of high-temperature physical problems 147
Norton, Thomas H. Foreign markets for American chemicals 699, 758
———The dyestuff situation in the U. S. 780

OLSEN, J. C. A new electrolytic method of sewage disposal.....530, 735, 793

PACK, CHARLES. Aluminium die casting a commercial achievement... 712
Palmer, Charles S. Chemical engineering versus engineering chemistry.... 203
Palmer, Leroy A. Gold milling in California; a comparison 617
Parnell, E. V. Autogenous welding of aluminium 712
Parker, R. G., and T. M. Lowry. Metallic filings 175
Parmelee, H. C. Cyanidation of low-grade sulphide ores in Colorado. 421, 477
Parr, S. W. An acid-resisting alloy..... 712
Patterson, W. Hamilton. An examination of firebricks 127
Peacock, S. Fixation of atmospheric nitrogen 325
Peffer, H. C. Chemical engineering course at Purdue 826
Pentland, W. J. The development of continuous counter-current decantation in cyanidation of slime..... 105
———Grinding ore for cyanidation; a suggested modification for all slime practice 205
———Tube-milling in all slime cyanide practice 204
———Tube milling; closed circuit..... 826
Petinot, N. Electric furnace in the foundry 650
Pettis, Edson S. Grinding ore for cyanidation; a suggested modification for all sliming practice..... 9
Peyton, Joseph L. Is duplexing slated for assassination? 397
Pierce, Daniel T. An interesting application of colloidal chemistry.. ... 408
———Mining and utilizing Trinidad asphalt 697
Pope, Fred J. Copper leaching..... 323
Porter, Alfred W. On Von Babo's law and Kirchoff's equation for the latent heat of dilution..... 499
Pratt, Edward Ewing. Opportunities for the American chemical industry.. 729
———Do we want a coal-tar industry?... 779
Prideaux, E. B. R. Note on the neutralization curve of boric acid..... 500
Pulsifer, H. B. Zinc oxide from lead blast furnace slag at South Chicago... 783
Pyne, Francis R. Notes on the reverberatory furnace 292
———Solution stratification as an aid in the purification of electrolytes..... 895

RAKE, JAMES LEWIS. Contributions of the chemist to the asphalt industry 283
Raltson, O. C., and A. E. Gartside. Leaching a zinc-lime ore with acids.... 151
Randall, Merle, and Scalione, C. C. Standardization of acid solutions..... 787
Rawdon, H. S. Standard test specimens of zinc-bronze 712
Read, Thomas T. Progress in copper metallurgy 657
Repath, Charles H. The design of modern copper plants 660
Rich, C. H. Carbon determination by the combustion method 347
Rich, C. H., and G. C. Whittam. The determination of chromium and vanadium in steel..... 238
Richards, Joseph W. The neutrality of science 408
———Quantitative blowpipe analysis.... 137
Richards, Robert H. Ore dressing..... 728
Ricketts, L. D. Copper leaching..... 319
Rigg, Gilbert, and Morse, Henry C. Influences of impurities in spelter. 712
Rittman, W. F.; Twomey, T. J., and Egloff, G. The estimation of aromatic hydrocarbons in cracked petroleum 682
Rittman, W. F., and R. J. Moore. The range of applicability of the liquid sulphur dioxide method for determining aromatic constituents in hydrocarbon mixtures 713
Robertson, T. D. Electric steel-making furnace 371
Roeber, E. F. Electrometallurgy..... 657
Ruder, W. E. Calorizing metals 325
Rutherford, Forest. Copper Queen Consolidated smelter 659

SADTLER, SAM P. Some American contributions to industrial chemistry 700
Saunders, Wm. L. Speech at Cottrell dinner 82
Sauveur, Albert. Beta Iron (Poem).... 352
———Metallography and the hardening of steel 655
Scalione, C. C., and Merle Randall. Standardization of acid solutions 787
Schoellkopf, J. F. The aniline industry from a manufacturer's viewpoint 780
Schüpphaus, R. C. Contributions of the chemist to the celluloid and nitrocellulose industry 286
Schwarz, Alfred. Repairing furnace linings with compressed-air gun and torch 582
Seaver, Kenneth. Silica brick for the by-product coke oven..... 861
Sharples, Philip P. Development of refined tars for use in road construction and maintenance..... 918
Shook, G. A. Refractometry..... 19
Shimer, W. R. Effect of finishing temperatures of rails on physical properties and microstructure... 178
Siever, H. F. Platinum boats for carbon determination by the direct combustion method 525
Smith, Edgar F. Electroanalysis..... 327
Snelling, Walter O. Government publicity methods 272
———Gasoline from synthetic fuel oil.. 180
Sperry, Edwin A. A modified iron-carbon diagram 471
Stadelman, S. I. Chemical engineering in nitrocellulose manufacture.. 361
Sticht, Robert. Pyritic smelting at Mount Lyell 116
Stone, George C. Development of zinc smelting in the U. S..... 726
Stone, I. F. The aniline dye situation.. 663
———Status of chemical industries in the U. S. at end of 1915..... 710
Summers, Leland L. Fixation of atmospheric nitrogen 241, 325
Swiggett, Glen Levin. Pan-Americanism 513
Symons, C. T., and K. C. Browning. A convenient thermostat for accurate specific gravity determinations and a gas pressure regulator 500

TABER, STEPHEN, and Thomas Leonard Watson. Geology of the titanium and apatite deposits of Virginia 573
Talbot, H. P. University and industry.. 941
Teas, William H. Contributions of the chemist to the leather industry. 285
Teller, Geo. L., and John A. Wesener. Contributions of the chemist to the flour industry..... 285
Thevenot, Gaston D. Contributions of the chemist to the brewing industry 285
Thompson, F. C. The elastic strength of metals 501
Thompson, M. deKay, and Ernest C. Crocker. Leclanche cells. 319
Thomson, Francis A., and Robert Keffer. The relative efficiency of various amalgams in the recovery of gold 367
Thrasher, Grafton M. The natural chill of cast iron and its significance in the manufacture of malleable castings 39
Thatcher, C. J. An improved diaphragm material—electro-filtros 336
Toch, Maximilian. The barium industry in the U. S. since the war..... 710
Townsend, Byrnes, and Brickenstein. Digest of electrochemical U. S. patents.....65, 131, 196, 268, 341, 403, 463, 575, 771
Twomey, T. J. W. F. Rittman, and G. Egloff. The estimation of aromatic hydrocarbons in cracked petroleum 682

VAN ARSDALE, GEORGE W. Copper leaching 322
Vogt, L. F. Naval consulting board.... 827
Vosmaer, A. Metastability of metals.535, 953

WALLACE, H. WALKER. Contributions of the chemist to the fertilizer industry 285
Walker, W. H. University and industry. 941
Walton, R. H., and Gregory T. Bailey. Separation of white metal and gunmetal borings 204
Washburn, Frank S. The cyanamid process 243, 309
———Fixation of atmospheric nitrogen. 325
Watkins, Joel H. White-burning clays of the Southern Appalachian states 179
Watson, Thos. Leonard, and Stephen Taber. Geology of the titanium and apatite deposits of Virginia. 573
Watts, Oliver P. Cleaning and plating in the same solution..... 327
Weber, Max C. Copper cyanide plating solution 255
Wedge, Utley. Copper leaching..... 321
Weeks, F. D. The Salida smelter..... 814
Weintraub, E. W. Fibrox..... 315
———Poronized cast copper..... 721
Weitlaner, R. J. Comparative furnace efficiency 357
———Furnace curves 425
Wells, A. E., and G. H. Clevenger. The co-operative metallurgical exhibit at the Panama-Pacific International Exposition 743
Wesener, John A., and Geo. L. Teller. Contributions of the chemist to the flour industry 285
Wesson, David. Contributions of the chemist to the cottonseed-oil industry 283
Westby, George C. A case for copper hydrometallurgy 295
Weston, Edward. Speech on receipt of Perkins medal 114
Wettstein, Thomas F. Effect of the war on the metal industries..... 712
Whitaker, M. C. Co-operation between university and industry..... 886
Whittman, G. C., and C. H. Rich. The determination of chromium and vanadium in steel 238
Willows, R. S., and F. J. Harlow. A simple method of deriving the Gibbs adsorption formula..... 499
Withrow, James R. Chemical engineering of the hardwood distillation industry 797
Withrow, James R., and Edward H. French. The hardwood distillation industry in America 30
Witte, Otto N. The proposed British dyestuff industry 246
Wood, D. Orson. The vapor pressure of concentrated sugar solutions. 499
Wood, John P. Dyestuff situation..... 781

YERBURY, H. E. Electrolytic action of return in electric tramways on gas and water mains..... 372

Metallurgical and Chemical Engineering

A Consolidation of Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII — New York, January, 1915 — No. 1

PUBLISHED MONTHLY BY THE
McGraw Publishing Company, Inc.
James H. McGraw, President.
Secretaryship vacant.
John T. DeMott, Treasurer.
239 West 39th Street, New York.

Telephone Call, 4700 Bryant.
Cable Address, Metchem, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Colo.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; *for all other countries,* $2.50. (*European exchange,* 10 *shillings,* 10 *marks,* 12.50 *francs.*)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

New York, January, 1915

Editorial:
Electrochemistry in America ... 1
Progress in Gold and Silver Metallurgy in 1914 ... 3
Copper Metallurgy in 1914 ... 4
Status of Zinc Metallurgy in 1914 ... 6
The Steel Trade's Poor Year ... 7
Readers' Views and Comments:
Electro-Analysis of Nickel. By D. F. Calhane ... 8
The Action of Fluorspar on Basic Open Hearth Slags. By W. S. Hamilton ... 8
Is There a Complex-Ore Problem? By W. Motherwell ... 8
Grinding Ore for Cyanidation: A Suggested Modification for All-Sliming Practice. By Edson S. Pettis ... 9
Tube-Mill Tonnage Calculation and Notes on Tube-Milling. By Justin H. Haynes ... 10
The Western Metallurgical Field ... 12
The Non-Ferrous Metal Market ... 14
The Iron and Steel Market ... 14
Notes ... 15
An Electric Muffle Furnace for the Determination of Carbon and Oxygen in Steel and Tungsten Powder. By Charles Morris Johnson ... 17
Apparatus for the Concentration of Sulphuric Acid. By William Mason ... 17
Refractometry. By G. A. Shook ... 19
Tube-Mill Tonnage Calculation. By Noel Cunningham ... 22
Comparisons of Electric Resistivities at High Temperature. By Carl Hering ... 23
Has Titanium Any Influence on the Properties of Steel? By F. A. J. FitzGerald ... 28
Findings of the Selby Smelter-Smoke Commission ... 29
The Hardwood Distillation Industry in America. By Edward H. French and James R. Withrow ... 30
The Natural Chill of Cast Iron and Its Significance in the Manufacture of Malleable Castings. By Grafton M. Thrasher ... 39
Philadelphia Meeting of American Institute of Chemical Engineers ... 41
Handling Iron and Cinder at the Blast Furnace. By J. E. Johnson, Jr. ... 43
Chemistry and Lighting ... 50
The Use of Hydrometallurgical Apparatus in Chemical Engineering. By John V. N. Door ... 55
The Chemical Trade Situation in Germany and Great Britain ... 59
Synopsis of Recent Chemical and Metallurgical Literature ... 61
Recent Chemical and Metallurgical Patents ... 63
A Norwegian Electric Steel Plant ... 64
Personal ... 65
Digest of Electrochemical U. S. Patents ... 65
Book Reviews ... 66

Electrochemistry in America

"There is a divinity that shapes our ends, rough hew them how we will." This quotation from Shakespeare which E. G. Acheson has placed at the head of the story of his life, might well be used as the leitmotif of a history of chemistry in America by any one who has the courage to write it. But who would in these days when history is in the making and American chemistry is expected, as never before, to solve problems and do things? Yet just because a detailed review of the many things that have happened during the past year in the different branches of the American chemical industries is inopportune now, the moment seems to call for a rough perspective sketch of at least a few tendencies which have been active in the shaping of American chemistry. If inspiration such as past achievements can give, is needed now by American chemists, it could not be found anywhere more markedly than in the story of American electrochemistry. No other branch of industrial chemistry has so distinctly the smack of American soil, shows so clearly the individuality of American conception and execution, as electrochemistry.

The story of American electrochemistry comprises not much more than the last two decades. Yet like anybody who is anything, American electrochemistry has a past. Without making impossible claims of impossible ancestors, we will mention one single name—Robert Hare of Philadelphia. He is perhaps most widely known as the inventor of the oxyhydrogen blowpipe, about which he presented a paper in 1801 before the Chemical Society of Philadelphia (by the way, the first chemical society in the world). But his influence was even broader in that he was the earliest American scientific experimenter and discoverer in electrochemistry. Hare interested himself in improvements in primary batteries. He introduced his "deflagrator" concerning which we quote from Silliman (from the delightful chapter on Hare in Edgar F. Smith's "Chemistry in America"): "Although the discovery of the constant battery by Daniell and of the double combinations of platinum or carbon with amalgamated zinc and nitric acid have rendered the old forms of this instrument no longer as useful as formerly, it is not less a proof of the merit of Hare's apparatus that Faraday, in 1835, after having exhausted his ingenuity and experience in perfecting the voltaic battery, found that Hare had already, nearly 25 years before, accomplished all that he had attempted, and with a noble frankness, worthy of all praise, he at once adopted Hare's instrument as embodying the best results then possible."

But even more remarkable is what Robert Hare was able to accomplish with his primary batteries as only

source of current. He improved Davy's electrolytic apparatus and process for obtaining the amalgams of calcium, barium and strontium from their chlorides. And he built an electric furnace which was the first electric furnace ever constructed and employed. Dr. C. A. Doremus presented an interesting paper on this furnace a few years ago before the American Electrochemical Society and the claim has been made that Hare must have produced in his electric furnace calcium carbide, phosphorus, graphite and metallic calcium. Whether he did or not, really matters little. But if he did, the question suggests itself: why did it take some 70 or 80 years to rediscover those substances and make them industrially?

One reason would be rather obvious. It is almost getting tedious to repeat that electric power cost is usually a large item in the cost sheet of electrochemical processes. With primary batteries as the only source of current, any development of industrial electrochemists and of electrical engineering in general was a clear impossibility. But when the dynamo made its commercial appearance it was quite natural that electric lighting and the mechanical applications of electricity such as traction and power transmission and distribution, first attracted the inventive talents of electrical engineers. Only after they had succeeded it became possible for the electrochemist to step in.

The work of the electrochemist is directed toward two aims. One is the production of electrical form chemical energy, the other is the reverse problem, the production of chemicals and chemical effects by electrical means and the storage of energy in chemicals. In the former field nothing that has the faintest resemblance to a revolutionary advance has been made in the design of the primary battery, which is still essentially based on the use of zinc as "fuel." The carbon battery is still a mere dream. Storage battery engineering, on the other hand, has passed with success through an extremely active career. In the development of the lead storage battery Brush in this country, like Faure abroad, devised in the early eighties of the last century an important improvement in the Plante lead cell consisting in the application of active material to a conducting support. Many smaller improvements in the lead cell have since been made by uncounted American battery engineers. But the only radical departure has been due to Thomas A. Edison, who invented and developed the iron-nickel alkaline storage battery.

Nor is this by any means Edison's only contribution to electrochemistry. Edison's revolutionary pioneer work on the carbon filament for the incandescent lamp was intrinsically of a chemical nature. All our modern illumination methods are essentially based on chemical research. And the indirect influence which Edison's personality has had on the evolution of American electrochemistry in shaping the career of such men as Acheson cannot be overestimated.

For this reason a few words may be said on Mr. Edison's well known method of working or procedure in invention, because in a way it is characteristic of the methods of working of the few big early electrochemical inventors who became the founders of the modern electrochemical industries of this country. Edison's principle is to take nothing for granted, to try everything, every material and every method—whether apparently possible or impossible, practical or impractical, probable or improbable—and to observe with utmost care in any case what happens. "Inspiration is only another way of spelling perspiration" is one of his slogans.

After all, this method of working is the only method possible in a new field in which there are absolutely no analogies to go by. This method was the only one possible in the pioneer work which led to the foundation of the big industries of carborundum and alundum, artificial graphite, calcium carbide, and so on, in the electric furnace.

When the electric furnace had been invented it was a tool to be used and abused. A very distinguished electrochemical inventor once said that it was all foolishness to rely on theoretical principles in high-temperature electric-furnace work, as there were neither analogies nor quantitative figures available. All that could really be done was to try an experiment and see what comes of it and observe whether the product is good for anything. This may sound a little rough, but it states the case truthfully with utmost frankness and it emphasizes in a very modest way the requirements in the mental make-up of an experimenter who proceeds along such lines. He must have the faith of a child, the courage of the pioneer who blazes the trail, and a power of keenest observation of the smallest indications of usefulness which appear in his experiments and which then become his guide for further work. Each of these mental requirements is rare, their combination is given to very few.

Acheson's glorious life work is a fine illustration of the momentous scope of various industries which, in the hands of a strong individuality, may grow with almost logical necessity out of a single and apparently exceedingly simple chemical reaction—in Acheson's case the reaction beteween silica and carbon. Acheson carefully noted anything he found in his carborundum furnace. And when he found something that was what it should not be, it was not despised as an undesirable impurity (which it would have been to an ordinary manufacturer), but it became to Acheson an indication of what would happen under changed physical conditions and a guide to new work. Thus the carborundum industry was followed by the industries of artificial graphite, silicon and siloxicon.

It is evident that work of this kind which creates new industries can only be carried through to success by strong individualities which naturally become a source of inspiration to others so that their work becomes a nucleus around which the work of others on a broader field crystallizes. Thus we have the early pioneer work of the two Cowles brothers which led to experimental work in many fields and to the industrial manufacture of aluminium alloys and other alloys in the electric furnace. And as a further perhaps purely psychological result, Cleveland became for a time an active center of electrochemical endeavor. Thomas L.

Willson, of calcium carbide fame, was once in the employ of the Brush Company in Cleveland, and Edward R. Taylor, the inventor of the carbon bisulphide electric furnace, also belongs to the group of old independent Cleveland electric-furnace men. Herbert H. Dow worked out at the Case School his process for sodium chloride electrolysis, and David H. Browne successfully separated nickel and copper from Sudbury ores for a series of years by an electrolytic process at Cleveland. And Cleveland is still the home of the amorphous carbon electrode industry, although the largest electrodes for electric furnace work are now made at Niagara Falls.

In fact, the chief center of electric-furnace activity in this country and in the world is now Niagara Falls. There we have the big electric-furnace industries of artificial abrasives, of calcium carbide and calcium cyanamide, of phosphorus, of silicon, and so on; of electrolytic-furnace processes we have the Hall aluminium process and the Castner sodium process, of electrolytic processes the manufacture of caustic and chlorine on a very large scale, of chlorate, etc., almost all processes used there being products of American genius. There are very few imported processes in use at Niagara. And it is but the plain truth to say that the Niagara Falls electrochemical plants demonstrate in broadness of scope and detail of execution in the highest degree the application of the American type of industrial genius to chemical industry.

While we are writing these lines, the news reaches us of the death of Charles M. Hall on December 27 at Daytona, Fla., where he had gone a few months ago in the hope of final recovery from a sickness of several years. Thus Hall has followed shortly Heroult, his friend and competitor in aluminium fame, into eternity. Hall in this country and Heroult in France invented simultaneously and independently the process by which aluminium is now made. And to Hall belongs the credit for having started the electrochemical settlement at Niagara. When in 1893 the Niagara Falls Power Company completed its power house the next step of finding customers for the power was not so easily solved, until the Pittsburgh Reduction Company with the Hall aluminium process broke the ice. How one after the other electrochemical industries followed is history.

It is impossible to go any more into details. Only with respect to the electrolytic production of caustic and bleach—a very flourishing industry just now since on account of the European war the importation of European bleach has stopped—we may point out the abundance of processes in successful commercial use. For the diaphragm process Le Sueur and Dow were early pioneers in this country, while probably the latest cell of this type is the German Billiter-Siemens & Halske cell, in use by the Niagara Alkali Company. The Pennsylvania Salt Company uses the Gibbs cell at Wyandotte. The mercury cathode process is represented by the Castner-Kellner cell in use on a large scale by the Castner Electrolytic Alkali Company at Niagara Falls. Analogous in principle to the mercury cathode cell, but using a fused electrolyte and a fused lead cathode for alloying with the sodium, was the ill-fated Acker process at Niagara. The Townsend cell is of decided originality; while it is usually classed as a diaphragm cell, it is really much nearer the mercury cathode cell, since the caustic soda as soon as formed is carried away by kerosene; in its development on a large scale for the Hooker Electrochemical Company at Niagara, Dr. Baekeland, among others has distinguished himself.

In the problem of the fixation of atmospheric nitrogen the credit of having done the pioneer work belongs to Bradley and Lovejoy, though their plant at Niagara was finally a failure. While the technical efficiency of output per kilowatt-hour in their process was practically the same as it is in the successful Birkeland-Eyde process in Norway, the question of commercial success turns on the cost of power and the power cost at Niagara is four or five times that in Norway.

But another application of electrochemistry to gas reactions, also of American origin, is proving a big industrial success in this country. The Cottrell process of precipitating dust and generally any liquid and solid particles from fumes and gases, now finds a steadily widening field of usefulness in smelters, refineries, chemical works, gas, cement and general industrial plants.

We have not even touched yet on the immense field of the applications of electrochemistry to metallurgy. But this is "another story" that may be left for another occasion. Surely even in the limited field we have considered, American electrochemists have shown that they stand on their own feet and can create industrial empires. When this country needs the help of the chemist —and this will be more and more the case—American chemists stand ready to do their duty.

Progress in Gold and Silver Metallurgy in 1914

As one of the most suggestive developments of the year we note the remodeling of the Dome mill, in the Porcupine district of Ontario. With the increase in reserves and the coincident decrease in grade of the ores of this mine, the milling capacity was largely increased and the flow-sheet rearranged to accommodate the lower grade ore to be treated. These conditions were met, as, in our opinion, they must always be met, by discarding all-sliming and supplementing the slime treatment with the installation of sand vats, a portion of the concentrates being reground in tube-mills.

Fine grinding, as with tube-mills, has done much for the advancement of the metallurgy of gold and silver, as indeed it is now doing for almost all concentration projects, of whatever metal-bearing ores. It has fairly won its place as standard practice and must continue to be a part of every scheme of treatment. But we have sometimes thought that our American metallurgists have been overzealous in their quest of the maximum extraction, and that fine grinding may at times have been unwisely developed to the extreme of total sliming. Tube-milling, particularly when carried to the point where all-slime treatment may follow it, is an expensive operation, and as the grade of the ore decreases, the in-

creased recovery due to the reduction in size of the particles may very well fail to offset the cost of power, material, and attendance expended for the reduction.

We think it may fairly be said that the lower the grade of the ore, the greater difference will exist between the maximum percentage of extraction obtainable and the maximum economic extraction, and that the latter will be lower as the grade of the ore is lower.

Briefly, we consider the work at the Dome to be soundly conservative; and from it we turn to examine, with interest, the radicalism of Mr. Jackling, as exemplified in the proposed Alaska Gold Mines mill.

Perhaps no work of recent years will be watched as closely by metallurgists as will this application of the accepted practice of the porphyry coper mills to the requirements of gold metallurgy. Breaking is to be followed by rolls, roughing tables, classifiers, regrinding plant, and concentrators, the aim being for concentrating efficiency rather than high recovery by amalgamation. Revolutionary as it seems, it may be inspired, and certainly not only the prestige of its sponsor but many strong features of the process itself merit the attention it will receive. To the onlooker this undertaking is particularly timely, since the increase in the falling weight of stamps has ceased, both abroad and in this country, where we understand that tests by one of the largest producers have indicated 1250 lb. as maximum falling weight obtainable without loss of efficiency.

With the continued development and widening application of cyanidation, amalgamation has in many instances been abandoned; in many others reduced to a position of minor importance. It is said that a good mine is a long time in aying; the same may be said of a good process, and we feel that amalgamation, far from being moribund, has its distinct field, doubtless narrower than formerly and yet of sufficient consequence to justify its consideration as a live process.

We note, in fine grinding, a drift toward shorter tube-mills, which has doubtless been influenced by the well-merited success of the Hardinge conical mill.

In the treatment of slime, undoubtedly the most interesting development of the year is the steady increase in the number of plants using continuous counter-current decantation for washing and dewatering slime This process, which at the time of its first application by John Randall failed through the unsuitability of the mechanical devices then available, has now, with the development of dependable slime-thickening tanks, fairly won a place beside the filtration processes, and is said to be doing most effective work. We look for its further development during the coming year

In precipitation, zinc, whether in the form of dust or shavings, but with the former making constant gains, continues to be generally used. The aluminium dust process, as used at the Nipissing low-grade mill, has brought forward the first innovation in this branch of the science which has come to the point of continuous and successful operation.

Conditions may no doubt exist where this precipitant, even though more expensive, has strong claims to superiority, but in our judgment they will be comparatively few and in all likelihood will be confined to ores where silver is the dominant metal, as the comparatively high alkalinity which is essential to the method would in certain instances inhibit extraction from gold-bearing sulphides. Broadly speaking, the process follows the general scheme used in precipitating with zinc dust, which has become the standard American method, except in small installations.

Passing from the metallurgy of gold, we consider the progress in the treatment of silver-bearing ores, in so far as the two metals may be considered separately.

Here we find the most interesting work of the year in the methods of the Nipissing mills, where the aluminium precipitation method, already discussed, is accompanied by the very interesting desulphurization method of Denny, wherein the ore, in a solution of sodium hydrate, is agitated in the presence of aluminium plates. As if this were not enough, the amalgamation method of their high-grade mill (although this perhaps antedates the period under review) is a further contribution from this source. All these innovations illustrate the constant widening of the field of cyaniding and the possibilities still awaiting the careful investigator.

In this connection we feel that the paper by Mr. G. H. Clevenger, in the July *Bulletin* of the American Institute of Mining Engineers, merits most careful reading by all metallurgists, as an illuminating and thoughtful article, delightfully sane in its consideration of the questions which it discusses, and, indeed, well worthy of the best traditions of the Institute.

In the course of this discussion, Mr. Clevenger expresses his satisfaction that, in the desulphurization process to which we have already referred, some one has at last brought forward a process depending upon reduction, as a foil to the innumerable oxidation methods now extant. We might continue the thought and express to the able staff of the Nipissing our appreciation of their efforts to give us some really valuable contributions to the development of the chemical side of cyanidation, which, coming as they do after years when all development seemed to be along mechanical lines, are more than welcome.

Chloridizing-leaching, as practised at Park City, and described by Mr. Theodore P. Holt, is another interesting contribution to the year's technology. The chloridizing roast is given in the Holt-Dern roaster, at a cost of less than $0.17 per ton, and the total cost of milling is placed at not over $1 per ton, with extractions of gold, silver and copper above 90 per cent.

In the technical press, two interesting controversies have continued their perennial course. The estimation of tonnage by specific gravity methods has grown in popularity, owing to its simplicity and cheapness. The experience of the Nipissing mill, cited by Mr. Johnston, confirms this view. He shows that the determination of weight, taken by a registering scale on the ore as it entered the mill, was checked over a period of seven months against the usual method of specific gravity tonnage determination, during which time a variation of only one-eighth of 1 per cent was noted. From this it seems reasonable to conclude that an intelligent application of the specific gravity methods can be depended upon for accuracy.

Not so satisfactory has been the discussion of the work of crushing, wherein the advocates of the laws of Rittinger and of Kick have belabored one another with hypotheses and equations innumerable. The struggle still rages, and we think that comment may well be deferred until next year.

In the line of assaying, Dr. Dewey has called attention to the revival of a method of directly determining silver in gold bullion, avoiding inquartation by alloying with cadmium, dissolving in nitric acid and titrating with standard sulphocyanide solution. This method, suggested by Balling and developed by Whitehead, had been lost sight of until revived at the San Francisco Mint, from which its use has been extended by the Mint Bureau.

Copper Metallurgy in 1914

Copper, more than any other metal, has been seriously affected by the European war. Many mines and some reduction plants are entirely closed, and mines and plants that are still operating are doing so under greatly reduced capacities, their output being about half the normal. At the beginning of the war an approach to a panic was noticeable among copper producers; all experimental work was discontinued, and betterments stopped. Gradually a feeling of confidence and security has been developing, and while the great foreign market for copper is still closed, yet with the establishment of equilibrium between production and domestic demand, a price has again been fixed which is very likely to be maintained.

Progress in copper metallurgy, during the past year, has been along the lines of the further application of flotation methods to the dressing of ores; of coal-dust firing to reverberatory smelting; increased activity in hydrometallurgical treatment, and the utilization of by-products.

By use of pulverized coal great economies in reverberatory smelting are accomplished. A greater tonnage of ore can be put through the furnace, a cheaper fuel can be used, a more complete combustion effected. Stoking and the handling of ash are eliminated. Furnaces of much greater size are possible; hence a more perfect separation of matte from slag is secured.

We are told of plans for building reverberatory furnaces with hearths 25 ft. by 175 ft. Coincident with the completion of these large reverberatory furnaces will be the blowing-out of blast furnaces, reverberatories being given the entire work of smelting all grades and kinds of ore. This means a marked increase in the percentage of copper on the charge, as concentration will be practiced to a much greater extent than formerly. By the adoption of oil flotation methods the losses in concentration, which occur mainly in the slime, will be very greatly reduced; and the cheap preliminary mechanical concentration, hitherto prohibited on first-class ores because of such losses, will be universally applied, except to self-fluxing ores. Another advantage of this plan will be that the large tonnage of limestone required under blast-furnace treatment of first-class, highly silicious ores, will be reduced to a minimum, for the concentrator will furnish a practically self-fluxing product and only enough lime will be added to the charge to produce a more desirable slag than the ferrous silicate furnished by the ore alone.

The practice in converting leady copper-matte, recently adopted at the Tooele plant of the Anaconda Copper Mining Company, is exceedingly interesting and may have a wide application. Under the old method of adding to the molten matte, in a basic-lined converter, sufficient silicious material to produce the standard slag, the fume passing to the bag-house was very corrosive and bags were destroyed to an extent that was practically prohibitive. The superintendent conceived the idea that a remedy might be found in converting in the absence of silica. This was expected to be accompanied by a building up of magnetite inside the lining, consequently limiting the life of each converter. Contrary to expectation the lining does not build up, and in addition a more complete elimination of lead and zinc is effected, together with the production of a fume which is non-corrosive to the filtering bags. To effect as complete elimination of lead and zinc as possible, the charge is over-blown, and as a result the basic slag is rich in copper. Both slag and matte are then transferred to other converters where, in contact with fresh copper matte, the final converter slag is brought down to a relatively low copper and silver content. This slag, of course, is re-treated as is usual with converter slags.

Efforts in the hydrometallurgical treatment of copper ores have been directed largely to methods of precipitation of the copper from solution. Preference seems to be in two directions: electrolytic and metallic iron precipitation. The former has many claims for first place, particularly because it furnishes a product that is at once commercial and requires at most only a furnace refining. The question of the production of foul solutions which complicate electrolytic precipitation in many cases is a serious one. The new plant at Chuquicamata is expected, according to recent reports, to produce electrolytic copper so cheaply that it can be placed on the European market at a price not exceeding 6 cents a pound.

Precipitation with metallic iron produces an impure cement copper, but this is of little moment when the leaching plant is connected with or near to a smelting plant. The amount of scrap iron is limited and a large plant will of necessity be compelled to seek some other source of metallic iron. Sponge-iron produced by reduction at relatively low temperatures, far below the melting point of iron, is an effective precipitant and will be largely used. Such iron can be made at a cost not greatly in excess of the cost of scrap iron, and with improved methods this cost may be still further lessened.

For some years a few smelters have been making arsenic in limited quantity, and much more would be made were there a market for the product. Cottrell fume-precipitation plants have been placed in successful operation at several smelteries and an exceptionally large one is planned for Anaconda. It is also planned to greatly increase the capacity of the Anaconda sulphuric acid plant, one unit of which was completed this year, so that not only will sufficient acid be produced for all hydrometallurgical needs, but also for the manufacture

of phosphate fertilizers. An attempt will be made also to save metals other than gold, silver, and copper, which have been the only ones heretofore receiving attention in copper smelteries. It has been found, further, that brick of a beautiful buff color can be made from tailings.

Status of Zinc Metallurgy in 1914

In reviewing the year 1914 in its relation to the metallurgy of zinc, the effects of the war greatly overshadow other considerations. The industry was not in a flourishing condition before the outbreak. The first half of 1914 had been a period of low metal-price, with small and uncertain margins for the zinc smelters. This was due in general to the business depression, and in particular to an increasing metal stock with irregular demand; to an uncertain ore supply and the stagnation in the iron and steel industry. When war was added to the existing burdens and uncertainties, managers and executive committees found it necessary to give almost undivided attention to finances, metal-price fluctuations, changing ore supplies and plant economies. There was so wide a disagreement as to the probable market position of the metal that metallurgical experiments and improvements were quite generally restricted, deferred or abandoned. Until the end of the war can actually be seen, it seems likely that, although better metal prices may obtain, and the situation look brighter for both miner and smelter, not much new work will be started.

In the smelting or metal-producing end of the industry, there have been, nevertheless, several interesting developments during the year. One was the tendency of the sponsors of those electric and electrolytic processes which have had more or less successful laboratory trials, to locate their first small commercial plants near the Mississippi River power supply. Although one of the chief aims and reasons for these processes—elimination of freight charges on low-grade ore—is thus ignored, there are other factors which outweigh this consideration, at least for these trial plants. They are cheap power, fuel, labor and supplies; a variety of ores and furnace products from which to choose; good transportation and near-by markets for products.

This tendency is being opposed by an active effort from a new source. The hydroelectric power companies of the Western mining states, in an attempt to equalize their irregular power load and to build up new business in mining regions at present inactive, have not only offered direct inducements to mining companies known to be considering electrolytic processes, but have sent into the field a staff of their own experts to work on processes and methods supposed to be suitable. This may perhaps be termed a flank attack on the complex-ore situation, and at least offers possibilities in the way of securing the best available apparatus, in marketing some by-products, and even in providing some financial assistance.

No radical changes in the retort-smelting of zinc ores can be chronicled. The year's record is again one of many small improvements in details of construction and operation.

Several of the American zinc smelting companies are now regularly marketing zinc dust which, as a precipitant of gold and silver in the cyanide process, is steadily replacing zinc shavings made from sheet metal. Zinc dust has heretofore come largely from Germany, the imported dust being considered more desirable than the domestic product on account of greater uniformity, both physical and chemical. Having had the market for this material practically forced on them, American managers quickly arranged to supply it and are rapidly learning to turn out a satisfactory product.

Improvements in methods of handling retort residues at the zinc furnaces have brought about such an increased commercial saving of gold, silver, lead, and copper from Western mixed ores, and have made results so regular and dependable, that such ores are now commonly purchased under sliding-scale schedules providing payment for all valuable metals contained. This has already made profitable several Western mines heretofore operated at a loss or not at all.

The fact is well known that not only do the residues from retort furnaces carry most of the gold, silver, lead, and copper in shape for recovery by lead or copper smelting, but so also do the residues from zinc-oxide furnaces. Many proposals to use the oxide furnace as a preliminary igneous concentrator have been made, and trials have proved that it is metallurgically possible. Economic factors, however, have made it questionable whether such processes will succeed if placed near the mines, where they are most needed. It would seem as though there must be favored locations where such methods might succeed. A beginning was made at Leadville during the year, and some progress reported; but at least another year will be necessary to determine the real possibilities of the plant.

In the mining and milling end of the industry, in which the ore producer is more directly interested, and seems likely to be for some time to come, there is not much positive and completed improvement to record. Wet concentration has advanced only in minor details. Some new work of interest has been done with dry concentration, but results cannot be said to be final. Magnetic and electrostatic separation hold their own in a field that does not seem to widen much. Chemical methods made little progress except along electrochemical lines. The work begun in chlorination in the Coeur D'Alenes is claimed to be very promising, but success is not yet a certainty.

The one really active process is flotation, and here the interest and work are widespread. It is unfortunate that the patent situation is so unsettled, because many really important discoveries are not being given publicity. This is particularly true with regard to selective methods aiming at separation among the several sulphide minerals. When once it has been definitely settled how far the claimed fundamental patents extend over the industry, it is certain that progress will be much more rapid. Enough is known now to make it certain that flotation can be made selective, but the degree of success and the methods to be employed will not be revealed for some time to come. While this is truly un-

fortunate from the standpoint of the mine operator, it nevertheless points decisively to the fact that flotation as a whole is by far the most important, inclusive and promising of any of the preliminary methods; that it is getting widespread and competent attention, and is certain to attain extensive application.

The Steel Trade's Poor Year

The year just ended has been the worst, from a commercial standpoint, that the steel trade has passed through since 1898, the last year of the great industrial depression. Production has been exceptionally small, about 60 per cent of capacity, while prices realized have been at the lowest average level since 1898.

The steel trade is distinguished from many other industries by the facility with which it makes remarkable records. It is, as Andrew Carnegie used to remark, either a prince or a pauper, though why he should be the man to say so is not so easy to fathom. Perhaps the one aspect mentioned represents his experience and the other his observation. There are some good reasons why the steel trade should experience violent fluctuations. One reason commonly assigned is that its products go very largely into permanent construction, but the volume of construction work in general hardly exhibits the wide variations that are observed in steel making activity, and the proportion of steel output that passes into current daily consumption, as in tin plate, for instance, is quite large.

The principal cause of the fluctuations in the steel trade is that stocks are carried by buyers and are not carried by sellers. The buyer is speculative to an extent. He anticipates his requirements when he thinks the market is going to advance and thus he helps to cause the advance. He curtails his stocks when he observes the market is declining and thus he encourages the decline. The buyer's conduct by no means represents pure speculation, for the nature of steel mill operations is such that when orders are plentiful long runs on a given size are specified for the individual mill and deliveries are made slow, while when orders are light rolls are changed or reset for the small specification and shipments are made promptly. As the mills grow busier the buyer must increase his stocks, as he can depend less upon the mill for quick shipment of the sizes and descriptions of steel he may need, while as mill activity decreases the reverse is the case. The average stocks of steel in the country are large, running well into the millions of tons and distributed in many quarters from the large jobbers' warehouses down to the country blacksmith, and the fluctuations from large stocks to very small stocks are necessarily counted in the millions.

There are other industries in which buyers carry stocks in widely varying amounts, but in such industries there is usually the opportunity for the producer also to carry stocks upon occasion. Copper is a highly speculative metal and buyers carry large or small stocks upon occasion, but the copper producers can readily carry stocks themselves, continuing production at an economical pace and withholding the product from the market. The steel manufacturer cannot do this, except in a few instances. Wire products, nails, fence, etc., can be stocked, and some descriptions of tubular goods can be stocked to an extent. Tin plate formerly could be, but sizes have been so multiplied that stocking is risky. Rails, bars, plates and structural shapes are not stocked, there being no standard sizes and specifications to which the mill can work to advantage. In the case of sizes that are common the cost of storage and rehandling would be unreasonably large.

The extreme leanness of the past year in the steel trade was due to a combination of circumstances. A rhythm of ups and downs had been established, but special conditions operated to make the trough in the curve particularly deep and wide. After the period of great activity ending late in 1907 the country found itself with large stocks, and a year of very light production, but with prices sustained by a common purpose among sellers, was needed for liquidation. In 1909 occurred a great wave of buying and the country restocked itself in the second half of that year and the fore part of the next, liquidating in turn thereafter. In 1912 the buying movement was repeated, though with less enthusiasm, the stocking up process continuing into 1913. At the beginning of 1914 the liquidation in stocks was not entirely completed, though probably nearly so. The trade was due, apparently, for an upward swing had not special conditions intervened. The first was the unwillingness or inability of the railroads to make their usual purchases, insisting that they needed an advance in freight rates to enable them to buy, and month by month during the first seven of the year the market waited for "the rate decision." Not only did the railroads not buy, but other buyers felt there was no occasion to purchase when the railroads were not figuring in the situation. The long expected rate decision, favorable by less than one-half the demands made, was announced on August 1 and fell absolutely flat, for the world was then experiencing the greatest shock in its history. The war then prostrated the steel industry afresh.

By the ordinary rhythm an important revival in the steel trade is months overdue, and the barriers to at least a moderate recovery are removed. By the recent reopening of the freight rate case the railroads are given almost all they originally demanded. The new banking and currency system makes it that financial troubles are largely past. The history of wars is that their worst effects in trade disruption are felt at the start, and the influence of the present war should now be decreasing. That humanity must pay a tremendous bill for this war is beyond question, but the payment will be made over a long period of years, not while the war is in progress.

As a matter of fact the steel trade has already started to experience at least a minor recovery. Beginning with a change in sentiment early in November the movement worked into a stage of heavier buying in December and at the opening of the new year the trend of prices in some commodities at least is distinctly upward.

Readers' Views and Comments

Electro-Analysis of Nickel

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I notice in your November issue an abstract of an American Electrochemical Society paper by Dr. W. Judson Marsh on the electro-analysis of nickel. The methods described have been in use at this laboratory for two years and found to give excellent results. The application of the base metal gauze was described in a paper from this laboratory published in *Metallurgical & Chemical Engineering*, February, 1914. We used a 100-mesh brass gauze, for the reason that a finer mesh can be obtained in brass gauze than in copper. This gave successful results in cases of zinc, nickel, copper, without any rotation. Currents of three and four amperes were employed at first and were cut at the end of the electrolysis to 1 to ¾ ampere.

D. F. Calhane.
Worcester Polytechnic Institute, Worcester, Mass.

The Action of Fluorspar on Basic Open-Hearth Slags

To the Editor of Metallurgical & Chemical Engineering.

Sir:—Any one familiar with basic open-hearth work knows that fluorspar CaF_2 is a very efficient agent in making the basic slag more fluid. Different theories have been advanced as to what reactions take place to give the above result, but none have appeared very satisfactory.

With fluorspar we add calcium which, as the oxide would give us a more basic slag, hence one more thick. We also add fluorine which we would expect to unite with silicon and pass off as a gas silicon fluoride. This removal of silicon would also made the slag more basic, hence thicker. However, we know that the slag is made thin to a very great extent when small percentages of fluorspar are added. The amount of fluorspar necessary being very small, the actual addition of a little calcium and removal of a little silicon would really give no apparent results.

The remarkable fluidity conferred by a small amount of fluorspar being added to a molten slag has suggested to me that the reaction may be a catalytic one; i.e. the fluorspar may be only an agent.

Reactions which I believe may account for the thinning of a basic slag are shown in the following two simple equations, although no doubt more complex reactions do take place.

Silica reacts with fluorspar to yield silicon fluoride and calcium silicate

$$3SiO_2 + 2CaF_2 = SiF_4 + 2CaSiO \qquad (1)$$

Lime reacts with silicon fluoride to yield fluorspar and calcium silicate.

$$3CaO + SiF_4 = 2CaF_2 + CaSiO \qquad (2)$$

In equation No. 1 the fluorspar reacts with the silica in the slag, giving us silicon fluoride (a gas) and calcium silicate, a fusible slag. Part of the silicon fluoride will escape but a greater part will react with the lime, giving us our fluorspar again and more calcium silicate, the fusible slag. This newly formed fluorspar will react with more silica as in equation No. 1 and the circle is repeated until all the silicon, fluoride gas has escaped. In each reaction some silicate of calcium is formed which is a slag with a low melting point, and the fluorspar has only been an agent to unite the silica and lime, either of which alone is fused with difficulty.

W. S. Hamilton
American Steel Foundries,
Granite City, Ill

Is There a Complex-Ore Problem?

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I have been too busy to reply sooner to Mr. Ionides' letter in your November issue, while this letter has also been delayed by the burning of bridges on the Nacozari Railroad.

I did not assume that the ore mentioned by Mr. Ionides was mined at Broken Hill, Australia. I cannot see what grounds he has for making that assertion. I merely stated that its zinc, lead and silver contents were about the same as that of the ore now being mined at Broken Hill. Even if this ore contains (as he says) a large percentage of pyrite (which the Broken Hill ore does not), I cannot see why that should "render it wholly unadapted to ordinary mechanical concentration." Is it not possible to do as was done at Broken Hill before the flotation process was introduced (as mentioned in a previous letter of mine)? That is to say, could not the lead and some of the silver be saved and the tailings stacked pending discovery of a suitable process? Would not that be better than selling the ore to a smelter and not only losing the zinc but paying a penalty on it?

I thank Mr. Ionides for his offer to put me in direct communication with the owner of this property and gladly avail myself of his offer.

Regarding the extraction at the Broken Hill South Mine during the latter half of 1913, I agree, after studying the figures supplied by Mr. Ionides from the *Australian Mining Standard* (which I had not previously seen), that, as the metal contents of this zinc *tailing* are not in a marketable form, they should not have been included in reckoning up the total extraction. The correct way would be to include the percentage of original contents for ore as contained in the zinc *concentrate* produced by the Amalgamated Zinc Company from the zinc tailing sold to them by the Broken Hill South Co., plus the percentage recovered in the concentrate produced from the slime by the new slime concentrating plant, which is a modification of the Minerals Separation process. I still maintain that a high extraction is obtained at Broken Hill from ore containing silver, lead and zinc—higher probably than at any other mining center—and that it is improving every year.

Mr. Ionides has a good deal to say about "commercial saving" and, of course, I agree that it is the basis of successful mining, but I understood the subject of our argument was mill extraction. The fact that the Broken Hill South Co. sells its zinc tailing to the Amalgamated Zinc Co. and only received about 5 per cent of its gross value in return in no way disproves my statement. If Mr. Ionides will study the figures of the Zinc Corporation, Sulphide Corporation, and Broken Hill Proprietary Co., which themselves treat the zinc tailing produced in their lead concentrating mills, he will see that the "commercial saving" of the zinc is much greater than 5 per cent.

Regarding the question of making a high grade or marketable concentrate from lead or copper slime, this is being done at Broken Hill (with lead slime) by flotation processes with which I am acquainted, and also I understand in Missouri, and I know of a place not 1000 miles from here (to quote one instance only) where they are making a concentrate containing 23 per cent copper from slime containing only 1.5 per cent copper. One of the flotation processes is used. Most of the copper is in the form of chalcopyrite. On a purely chalcocite slime it is possible to make a much higher-grade concentrate.

I have just come across the following figures relating to the operations of the Zinc Corporation at Broken Hill during 1913: "The zinc concentrator treated 350,120 tons of tailing assaying 14.16 per cent zinc, 5.95 oz. silver and 5.7 per cent lead, for a yield of 102,850 tons of flotation concentrate, assaying 44.2 per cent zinc, 12.1 oz. silver and 12.5 per cent lead. The re-treatment of this product by tabling and the Horwood process combined yielded:

	Zinc, %	Silver, %	Lead, %
81,820 tons zinc concentrate assaying.....	47.1	10.5	7.7
3,082 tons Horwood zinc concentrate assaying.	47.3	15.3	9.5
12,623 tons lead concentrate assaying.....	15.4	31.8	55.4
1,498 tons Horwood lead concentrate assaying.	18.8	35.3	32.9
3,442 tons zinc slime for re-treatment.....	36.7	24.5	16.2

"The sterling value of these products (except the last) was 72 shillings and eight pence per ton of reflotation concentrate, the enhancement, as the result of re-treatment, being £106,985. As the cost of retreatment amounted to £25,035, the profit was £81,950.

"The cost of treatment of tailings in the zinc concentrator (including regrinding) averaged 10 shillings and 2 pence per ton (say $2.44), of which 18 cents per ton represents the cost of operating the Horwood plant."

The following extract from the *Barrier Miner*, published at Broken Hill, may be of interest:

"Tests made on Tasmanian ores show that 85 to 90 per cent of the zinc can be recovered as a high-grade zinc concentrate, assaying 57 per cent zinc, while the same percentage of the lead contents can be recovered in a separate product along with the iron contents of the ore (in a form which makes the material practically self-fluxing), accompanied by also 75 to 80 per cent of the total silver contents of the ore and about 90 per cent of the gold contents."

Do any of your readers know of any place in America where anything approaching this is being done?

Nacozari, Sonora, Mexico. W. MOTHERWELL.

Grinding Ore for Cyanidation; A Suggested Modification for All Sliming Practice.

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I wonder why we have not heard more about the system of classification of pulp and solution before tube-milling in the all-sliming plants, as suggested by Mr. Pentland in your October issue. Even for obtaining higher-grade solutions for precipitation from the first thickener previous to final agitation and counter-current washing, if not gaining ultimately higher *indicated* extraction.

The two and three-stage crushing plants present unique means of classifying pulps as Mr. Pentland has outlined, and it seems that cyanide metallurgists are slow to perceive and grasp the opportunity where they are not using the counter-current decantation, and depend on filter displacement. What is true in one case, may be adverse in another, but where a large tonnage of solution is used, as in the decantation system, these points undoubtedly should be investigated as otherwise.

I will cite an instance in Arizona, a plant I operated some three years ago, where radical changes were necessary along these lines.

We were confronted by numerous problems. The main apparatus was well enough arranged, but the pulp flow and solution classification did not prove efficient for actual recovery. The indicated dissolution of gold values was simple enough, but it was necessary to make the system more continuous and deliver less dissolved values to the filter.

The crushed ore and solution as delivered and discharged from a Chilean mill, passed a 16-mesh screen to an Akins classifier, where the sand was separated from the slime (24 per cent), and conveyed direct to the 5/22 tube-mill. The slime and excess solution flowed to the first thickener. The gold values were principally in the sand material, and about 60 per cent of the extraction took place in the tube-mill circuit. Instead of returning the tube discharge (1 to 1) to the Akins, a deep cone was installed to receive this partly reground pulp for returning the unground sand to the tube. The density of this pulp was too thick for proper classification. Therefore, as head room premitted it, a portion of the slime and excess solution was tapped from the end and bottom of the Akins to dilute the cone feed, maintaining an overflow of 2½ to 1 ratio. This finished product passed direct to No. 1 agitator, being of the proper density for agitation, where most of the remaining values went into solution. This pulp, after partial treatment, subsequently passed continuously to No. 1 thickener and the clear overflow carried away 80 per cent of the already dissolved values, or 60 per cent of the original ore values plus assay of ongoing mill solution, to precipitation.

The discharge from No. 1 thickener (sand and slime 1 to 1), bypassed No. 1 agitator to No. 2 agitator. Thus the sand (150 mesh) obtained longer treatment while the slime received one-half the treatment originally planned. After installing these improvements the mill tonnage was materially increased. The extra sand treatment enabled less grinding, and the only reason this change was made in the upper part of the plant was to produce high-grade solution for precipitation from No. 1 thickener.

The plant had only two thickeners, one before agitation and the other following to thicken for filtration.

Our ultimate object in view was to obtain as low a grade of pulp as possible for filtration. The overflow from the No. 2 thickener originally passed to precipitation and then to the head of the mill. This was discontinued and in changing the system, the dilute filtration solution was united with the barren precipitated solution, delivered to No. 2 thickener and discharged under the surface of overflow level, below the inflow of pulp from the agitators. In this manner the solids settled in a more barren solution than otherwise. When the thickener is large enough, the scheme of upward displacement works ideally on tube-mill product, and we gained the desired results of delivering a practically barren pulp to the filter.

To overcome the necessary headroom required, and supplying a thicker flow to the tube-mill, I would suggest it better to use the cone for the first classification, providing a Dorr or Akins classifier will separate fine sand from course economically of pulp with the density of 1.250 finished product; suitable for direct agitation. Further in this arrangement and in some cases I suggest a large thickener cone (with goose neck), for sluffing off part of the first crushing solution from the first classifier dilute overflow. This will result in richer and less solution for precipitation, where much solution is used in the first crushing, and low grade. Likewise the discharge of No. 1 thickener would be slightly richer using the sluffing-off tank, but this solution could pass to No. 2 thickener and perhaps perform its duty to better advantage.

Of course, these additions require more headroom, or returning to the old system of elevating separately the tube-mill discharge in returning to the circuit.

In many cases the first slime produced is the more refractory part of the ore, causing higher cyanide consumption, difficult to settle and filter, often requiring more solution ratio and longer treatment, whereas the difficulty in the sand treatment is overcome by the fine grinding. However, in a direct cyanide plant the sands portion from the first crushing generally assays the higher, or contains the larger percentage of original values, and my experience has been that the greater ex-

traction takes place during the fine grinding and the first eight to twelve hours air agitation of the pulp of more dilute consistency. Where the extraction has been poor in the tube circuit and the chemical consumption high, with an six to eight-hour agitation in a restandardized solution and more dilute pulp, directly after the gold or silver has been cleaned by the grinding process, I find a high percentage of extraction takes place.

The only difficulty experienced with the above procedure was the accumulation of coarse sand in the first agitator, but in our case the extraction was better, since this product received longer treatment. We would run continuously for a number of days, and then partly empty the agitator for a fresh start. In treating 150-mesh sands by agitation where the colloidal or first slime has been removed, a shallow tank with numerous air lifts, such as the Parral, would insure less short-circuiting or concentration of the coarse sand. The material treated in a low tank with numerous lifts has a chance to circulate up and down and around the entire tank before passing out. The Dorr agitator would undoubtedly guarantee less danger of this segregation than would the ordinary Pachuca.

Edson S. Pettis.

San Francisco, California.

Tube-Milling Tonnage Calculation and Notes on Tube-Milling.

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I have read with much interest Mr. Noel Cunningham's article on calculating tube-mill tonnage, appearing on page 22 of this issue, and have carefully studied his method of calculation and the equation obtained. Mr. Cunningham has handled the subject in a novel manner, and has presented something in which all operators will be interested. A study of his calculation leads to some interesting speculation on the general subject of tube-milling, relating to current practice in all-slime cyanide practice.

In my opinion Mr. Cunningham's equation is correct for certain ideal conditions which, however, are not attained in practice. The necessary ideal conditions would be that the total tonnage be ground to minus 200-mesh, or, in other words, that the quantity of minus 200-mesh pulp overflowing the classifier be equivalent to the total battery tonnage. Of course this is not the case, as there is always a percentage of plus 200-mesh material in the classifier overflow.

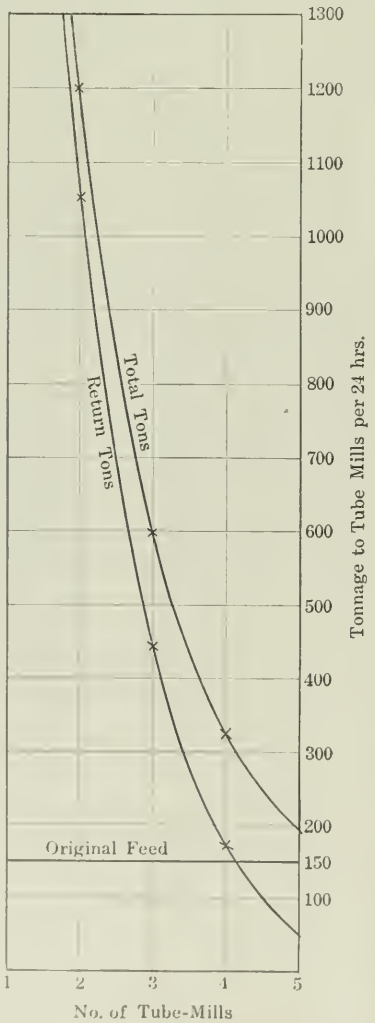


FIG. 1—SHOWING ACCUMULATION IN TUBE FEED DUE TO INSUFFICIENT NUMBER OF TUBE-MILLS

In order to insure having the classifier overflow all ground to minus 200-mesh, it would be necessary to have sufficient tube-mill capacity to grind all the battery oversize to this mesh, and, as it now seems to me, do this in one passage of the pulp through the tubes. Of course, if this were the case, there would be no need of running the tube-mills in closed circuit with classifiers.

All this leads to some interesting speculations on current tube-mill practice in cyaniding, with particular reference to (1) the conditions most favorable for obtaining the maximum fine grinding in a tube-mill; (2) cumulative effect of returning to a tube-mill a part of its discharge that has not been ground to the desired degree of fineness; and (3) the consequent propriety or impropriety of the "closed circuit." Mr. Pentland has touched on some of these points in his article on tube-milling, published in your December issue, page 750, raising some of the same questions from the viewpoint of correct moisture content of tube-mill pulp.

If a tube-mill is unable to crush the entire oversize from its quota of stamps to minus 200-mesh, with one passage of the pulp through the mill, there will be a return of oversize from the classifier. This, in time, increases the load on the tube which, in turn, produces a diminishing percentage of minus 200-mesh material and an increasing percentage of oversize. If a certain amount of this oversize is allowed to overflow the classifier, equilibrium will be established; but if an attempt is made to hold the classifier oversize at minus 200-mesh, the accumulation in the tube-mill will ultimately reach a point where the machine will do little or no work. I am sure all cyanide operators have had such an experience.

Recently there was published[1] a series of tables on tube-milling, some of which are pertinent to this discussion. One of them, given below, bears on the accumulation of oversize under closed-circuit conditions, and the number of tubes required to perform a certain duty.

Table I.

Relation of Feed per Mill to Tonnage of Return Feed

Tube-Mills Operating	Tons Dry Sand per Day—Feed per Mill	Total Feed to All Mills	Total Return Feed
5	40	200	50
4	80	320	170
3	200	600	450
2	600	1200	1050

Note.—In each case the total initial feed of concentrator tailings passing to the tube-mills was 150 dry tons per 24 hours.

A study of these figures, which are also plotted as a curve in Fig. 1, shows the accumulation in tube-mill feed due to the increasing quantity returned. When this accumulation begins to reach serious proportions, it naturally shows itself in the screen analysis of the classifier overflow; that is, by an increasing amount of plus 200-mesh material. Many cyanide operators (I have done the same thing in the past) will attempt to adjust this by changing the baffle on the classifier or by diluting the battery pulp, so that only the finest material will overflow the classifier. On second thought, however, it will appear that this merely makes matters worse and allows a greater accumulation before the inevitable equilibrium is again established by the overflow of more plus 200-mesh material from the classifier. When such a condition does arise there is no way of adjusting the classifier to prevent it, and the only solution lies in increasing tube-mill capacity. For this reason I consider any adjustment of the classifier as utterly useless. That machine cannot be made to control a condition that is created in the tube-mill and for which the latter is responsible.

This brings up the matter of closed circuit, for if we

[1] *Eng. & Min. Jnl.*, Sept. 2, 1914.

increase tube-mill capacity to a point where it will grind the entire oversize as desired, we have then reached a point where there is no need of returning the discharge to the classifier, as the product from the tube-mill will then be practically the same as the classifier overflow.

From the foregoing it can be seen that in a plant curve in Fig. 2 the data from these tables as relating to the minus 200-mesh pulp produced, except that I have shown actual tons instead of percentages as originally given. This curve shows that, with an increase in the tonnage fed to the tube, the actual *quantity* of material ground to minus 200-mesh increases.

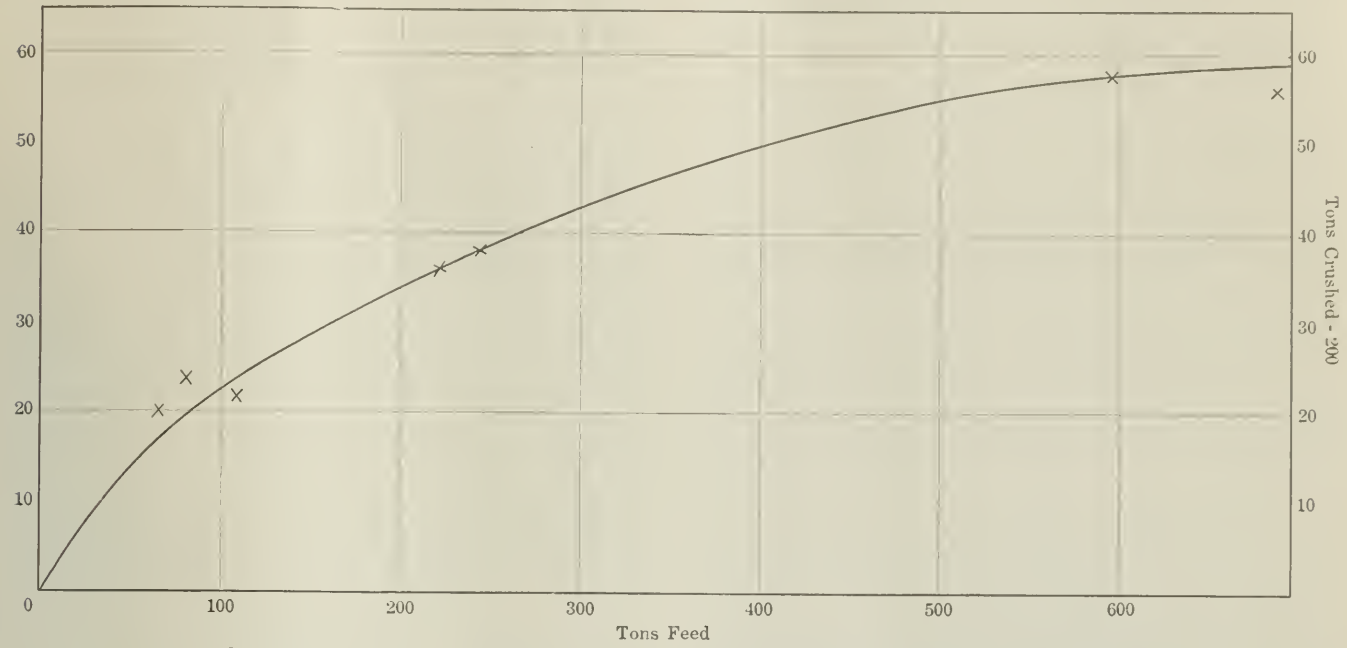


FIG. 2—TONS CRUSHED TO MINUS 200-MESH IN TUBE-MILLS AT VARIOUS RATES OF FEED

containing, say, two tube-mills in parallel, neither of which will handle its tonnage so that the product does not need classifying, it may be possible, by putting the tube-mills in series, to obtain this result. In fact, this was proved to be the case at the Liberty Bell mill, where two tube-mills in series gave a finer product than three tube-mills in parallel in closed circuit.

Other tables appearing in the source already mentioned show the effect on the grinding obtained in tube-mills by varying the tonnage fed. I have plotted as a

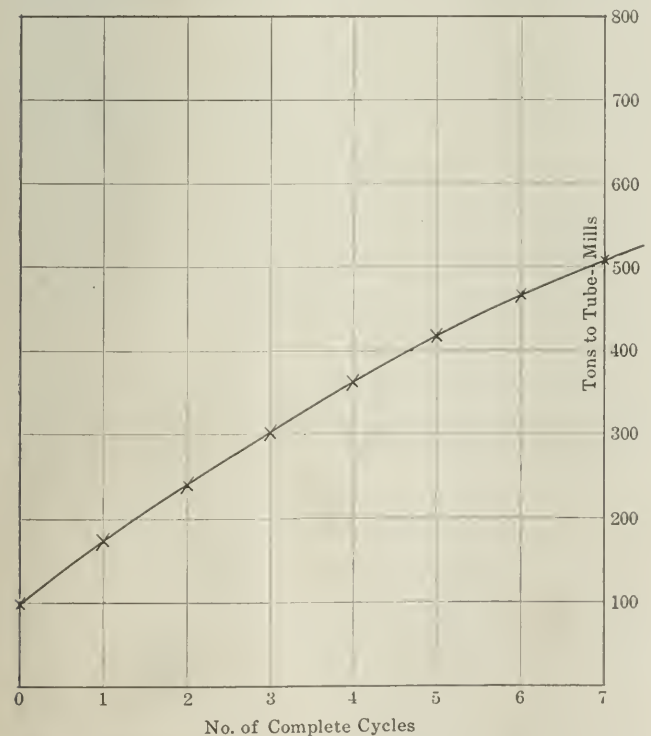


FIG. 3—SHOWING ACCUMULATION OF PULP IN TUBE-MILL CIRCUIT WITH 100 TONS PER CYCLE OF INITIAL FEED

But the *percentages* of that product is steadily decreasing, which shows that the feed is increasing faster than it is ground to the desired degree of fineness. In other words, the *per cent* of minus 200-mesh material produced is approaching zero as the feed increases, and will ultimately reach a point where none of that product will be made. The following table gives the figures from which the curve is plotted.

TABLE II

Effect of Varying Tonnage in Tube-Mills

Tons feed 24 hours	67	80	109	217	239	570	693
Per cent minus 200-mesh in discharge	30.03	30.15	20.04	16.56	16.00	10.28	8.09
Tons minus 200-mesh in discharge	20.12	24.10	21.84	35.93	38.24	58.59	56.06

The curve given in Fig. 3, which is derived from the data afforded by the curve in Fig. 2, also has a bearing on the subject of accumulation. Suppose we arbitrarily consider the flow of pulp as intermittent or occurring in cycles, and assume 100 tons of oversize coming from the batteries to the classifier in each cycle. Then in the initial cycle we will deliver 100 tons to the tube-mill, and of this (see Fig. 2) 23 tons is ground to minus 200-mesh, leaving 67 tons of oversize to be added to the next 100 tons of original feed, making a total of 167 tons in the second cycle. By continuing this calculation we get the results plotted in Fig. 3, showing the accumulation in the tube-mill circuit. The only way of preventing this accumulation is to provide sufficient tube-mill capacity to grind the battery oversize in one passage through the tube, whereupon the curve of Fig. 3 would become a horizontal line. That this accumulation does not occur in practice is due to the fact that the classifier acts as an equalizer, maintaining equilibrium by overflow plus 200-mesh material.

The figures given in these tables and curves are not intended to represent general tube-milling practice, and the actual data given will vary widely from similar data on other ores and with other mills, but they illustrate the point I am trying to make.

The general accumulation of ore in the tube-mill circuit is enormous, and is not generally realized by tube-mill operators. As shown in Table I, where two tube-mills were used they were ultimately grinding every twenty-four hours seven times the tonnage of the batteries; and I think I can safely say that this is no exception, as the tonnage usually ground in tube-mills is tremendous as compared with the total tonnage coming from the stamps.

While this discussion has not all been pertinent to Mr. Cunningham's article, it has been suggested by it and by Mr. Pentland's notes on tube-milling for all-slime cyanide practice. The meat of the entire matter resolves itself into the fact that with a certain design of classifier, tube-mill and stamps, working on a certain ore, the degree of fineness of classifier overflow becomes a constant when equilibrium has been established. Absolutely the only way to obtain a larger percentage of minus 200-mesh material in the final product is to increase tube-mill capacity, in which case the closed circuit will not be needed. To put this condition into a formula would require a separate formula for each tube-mill, and a constant due to the ease with which the ore is ground.

Justin H. Haynes.

Denver, Colo.

The Western Metallurgical Field

Optimism in the Mining and Metallurgical Industry

We hold to optimism because we know that temporary depression is ultimately compensated by activity and prosperity. There are growing evidences that we have passed the period of shock following the declaration of war in Europe, and that we are readjusting ourselves to the new conditions forced upon us. In the West there is a feeling that capital is going to seek investment in mining and metallurgical enterprises, and this sentiment also holds in some quarters of the East, according to reports of engineers who have recently investigated the situation.

At the Phoenix, Ariz., meeting of the American Mining Congress, held last month, Mr. George Otis Smith, director of the United States Geological Survey, expressed the spirit of optimism which is now prevailing. "Europe's war finds its echo in America's industry. Evidence of business betterment is before us on every hand, and the reasons for optimism are many. Foreign orders have started factory operation which at once tends to relieve the stagnation in the steam-coal trade; the steel situation has turned from serious depression to rapid improvement, and the whole mineral industry may soon expect to share in this general business improvement. To-day the financial horizon is so nearly cloudless that the prophets of bad weather have little upon which to base their predictions. Coming down to bottom facts, the United States will profit by the European war only as the nation makes larger and wiser use of its mineral resources."

Heavy Exports of Zinc

Figures compiled by the bureau of foreign and domestic commerce of the Department of Commerce, show that the exports of domestic zinc during September, October and November exceeded the total for the seven-year period ended June 30, 1914. The exports during this period rose to the unprecedented total of 65,504,574 lb., valued $4,443,381, as compared with 1,346,877 lb. valued at $80,756 in the corresponding period of 1913. The year 1897 was the former high-record year in zinc exports, when the total was 35,869,987 lb. The recent large exports of zinc were for England, Scotland, France, Italy, Denmark, British Africa and Australia. The exportation during the three months above mentioned was about 10 per cent of the domestic production which, in 1912, amounted to 647,814,000 lb.

Mackay School of Mines

The Mackay School of Mines of the University of Nevada has taken steps to increase its usefulness to the state by offering a short course in prospecting. It is expected that attendance on the lectures to be given will have the effect of making prospecting more intelligent and efficient, and consequently contribute to the advancement of mining in Nevada. The course will be offered for four weeks during February, 1915, a nominal fee of $5 being charged. Instruction will be given in excavation of earth and rock, prospecting, mineralogy, geology of mineral deposits, assaying, gas engines, first aid and mining law.

The metallurgical laboratory of the Mackay School of Mines is well equipped for instruction to supplement lectures given in the classroom. The recent addition of a small filter-press to the cyanide equipment makes that department practically complete. It is the policy of this school to use small-size machinery in its laboratory work, rather than standard machines that are too large for frequent use by students. Equipment for metallography and mineralography is now available for the microscopic study of metals and minerals, whereby knowledge is gained that is of use in determining the methods of treatment to which ores are amenable.

Molybdenum in Colorado

The Primos Chemical Co., which already is engaged in mining and treating tungsten and vanadium ores in Colorado, has recently become interested in property at Georgetown, Col., where molybdenum ore carrying some gold and silver has been developed. The company has been engaged in making some surface improvements and underground developments, with the probable intention of erecting a treatment plant of some kind when metallurgical tests have been completed. It is likely that nothing more than some form of concentration will be attempted at the mine, leaving reduction work to be done at an Eastern point.

New Cyanide Mill for Pittsburgh-Dolores Mining Co.

The Pittsburgh-Dolores Mining Company is remodeling the old Rockland mill, situated 27 miles from Yerington, Nev., into a modern cyanide plant. The former mill was erected as a leaching plant, but was not a success and has not been operated for seven years. Preliminary tests on the ore indicated that an extraction of about 95 per cent could be obtained from $12 ore by grinding to 100-mesh and cyaniding. The old, coarse-crushing equipment was therefore supplemented by a 5-ft. x 18-ft. tube-mill, which will grind in closed circuit with a Dorr classifier.

The new mill will have a daily capacity of 60 tons and will adopt continuous decantation. In the old leaching equipment there were five steel tanks, 30 ft. in diameter by 5 ft. in depth. These will be converted into Dorr continuous thickeners. The tanks are shallow, but on account of the large settling area afforded for the tonnage to be treated, and the rapid rate of settlement of the ore, it has been considered safe to commence operations with shallow tanks. Provision has been made, however, for deepening the tanks to 8 or 10 ft. if necessary, by equipping the thickeners with long driving shafts. It may be that 5 ft. will be sufficient depth for such quick-settling material, and that a low-moisture discharge will be induced by the coarse sand packing near the point of discharge.

As the old leaching vats were arranged on the same

level, they will not be changed in the remodeled plant. This will make it impossible to get gravity flow of solution through the continuous decantation system in the preferred manner, and in order to secure thorough mixing of the thickened slime and decanted solution passing to the various thickeners, mixing cones will be installed. The mixture discharged from these cones will be elevated to the thickeners by air-lifts which will be regulated by floats within the cones, rigidly connected with the valves on the air line.

Agitation will be continuous in three Dorr agitators, 22 ft. in diameter and 19 ft. deep. Compressed air will be delivered by a 12-in. x 12-in. compressor run by a 10-hp motor. This will give 150 cu. ft. of air at 20-lb. pressure, which will be used for agitation and air-lifting. The manner of connecting the agitators for continuous work is shown in the sketch, Fig. 1. The adjustable transfer pipe makes it possible to draw off pulp of uniform density and prevent classification within the agitators. A feature of the plant is the small power requirement for the continuous decantation department.

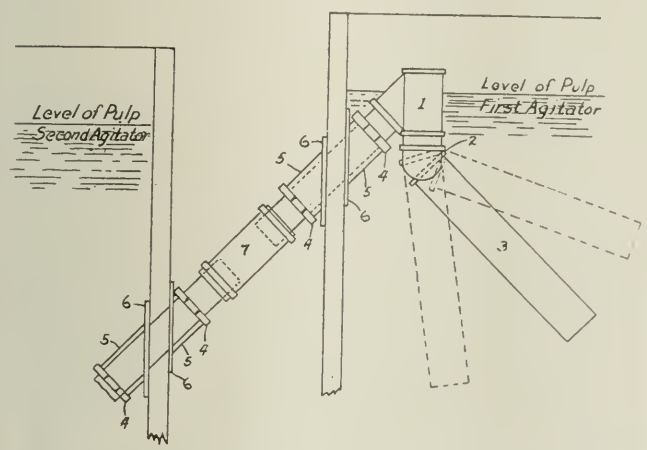


FIG. 1—CONNECTIONS OF DORR AGITATORS IN SERIES

1 Standard C. I. "Y" Bend. 2 Double E II. 3 Adjustable Transfer Pipe. 4 Lock Nuts. 5 C. I. Bevel Hollow Washers to be pressed against gaskets (6) by lock nuts (4). 6 Gaskets. 7 Flexible Rubber-Tube connection.

A 10-hp motor is provided for the operation of three agitators, five thickeners, two solution pumps and five diaphragm pumps. Mr. E. J. Schrader, of Yerington, Nev., is manager for the company.

Normal Conditions Exist in Cobalt

With the resumption of operations at the Buffalo low-grade mill on Dec. 7, mining and milling conditions at Cobalt, Ontario, are about the same as before the declaration of war. The Buffalo company suspended operations four months ago, starting work in the mine after a few weeks, but doing no milling until the date given above. The high-grade mill is still closed, but as it handles concentrates from the low-grade mill, it is likely that it too will be started soon. Weekly shipments from Cobalt continue to increase as the aspect of the silver market improves.

The Cyanide Situation

Speaking before the Mining and Metallurgical Society of America, at a meeting of the New York Section, Mr. Otto Ruhl, of Roessler & Hasslacher, said recently that his firm began the manufacture of potassium cyanide at Perth Amboy, N. J., in 1890. The old method of using potassium ferrocyanide was employed. The first sales were not for gold extraction, but for fumigation of trees. Seven years after beginning production, the first carload was sold at 45 cents per pound. When the Dingley tariff came into effect in 1897, the rate of duty on cyanide was reduced from 25 per cent to 12½ per cent *ad valorem*, and the domestic production of cyanide was ended until 1902. In that year Roessler & Hasslacher took up the manufacture of sodium cyanide by the synthetic process of Hamilton Y. Castner, an American chemist. "It took fully ten years to reach the high standard of sodium cyanide which we are now producing, equivalent to 128 per cent to 130 per cent potassium cyanide, now universally recognized as the only proper material for electroplating, fumigation and gold extraction purposes." When cyanide was put on the free list by the Wilson tariff act in 1913, the output of the cyanide factory at Perth Amboy was not equal to the growing needs of the country, and it was necessary to import cyanide. At the outbreak of the war it was planned to operate on a larger scale and meet the increased demand. Mr. Ruhl gives the annual consumption of cyanide in the United States as 2000 tons, and of Mexico 5000 tons. According to figures of the United States Geological Survey given in our last issue, the domestic consumption is about 2500 tons per annum. Mr. Ruhl closed with the statement that "under the Dingley tariff of 12½ per cent *ad valorem*, an amount of protection with which we were quite satisfied, we were able at all times to supply the whole American demand. The raw materials we consume are sodium, ammonia and carbon."

Company Reports

Stratton's Independence, Ltd., has issued its annual report for the period ended June 30, 1914. The production of shipping ore, both on company and lessees' account continues to fall off as compared with previous years, and is expected to so continue. The mill treated during the year an average of 11,156 tons per month, the largest tonnage handled to date. The total working cost was $1.3811 per ton, the lowest to date. Deducting the cost of getting ore from the dump, the actual milling cost was $1.27 per ton. Extraction was a round 80 per cent, having increased 1.5 per cent over the previous year. The grade of mill ore fell from $3.076 in the previous fiscal year to $2.879 in the current year.

The mill handled 88,192 tons of dump ore and 45,683 tons of low-grade mine ore. The average gold content was 0.14396 oz. per ton, or a total of 19,273,469 oz. There was recovered in concentrates 7,654.77 oz., or 39.72 per cent; and in cyanide bullion 7764 oz., or 40.28 per cent; total, 80 per cent. The first-grade concentrate averaged 4.358 oz. gold per ton; second grade, 1.848 oz. These products were sold to smelters. The milling cost per ton was divided as follows:

Coarse crushing and sorting	$0.1563
Fine Crushing, concentrating and treating concentrate	0.5040
Cyaniding and special chemicals	0.1672
Miscellaneous expense	0.1425
Total milling cost	$1.2700
Mining dump ore	0.1100
Total cost	$1.3800

The gross profit from treating ore in the mill was $127,760, of which $26,251 was paid to the mine department on the usual schedule of treatment charges for milling low-grade mine ore, leaving a net profit to the mill of $98,509, on the treatment of 133,875 tons of ore.

The third quarterly report of the **Butte & Superior Copper Company** for 1914 shows 100,600 dry tons of ore milled. The average content was 18.58 per cent zinc and 8.64 oz. silver. The quantity of concentrate produced was 60,974,968 lb., containing 33,121,312 lb. metallic zinc, or 54.32 per cent. The average silver con-

tent of concentrate was 24.15 oz. per ton. Zinc recovery averaged 89.14 per cent. Milling cost $2.049 per ton. The estimated net profit for the quarter, calculated on spelter at 5.11 cents, was $499,136. The net spelter return per ton of ore, including estimated value of lead concentrates and zinc residues, was $10.21 as compared with $8.44 for the previous quarter.

The Non-Ferrous Metal Market

Since our last monthly report the prices for metals except tin have advanced, in some cases substantially. Following a brisk domestic demand for copper, European buying strengthened the market. Lead has remained at a low price, slightly in advance of a month ago. Spelter has advanced sharply, due principally to sales to Europe. Tin has declined, following a decline in London and lack of interest among consumers.

Copper.—Sales have been reported at 13 cents, and with renewed selling to Europe the market is firm. Most of the business, however, has been transacted at about 12.75 cents, New York.

Lead.—Business has continued light, but there is a sentiment that foreign countries may soon be in the market for this metal. New York quotations are about 3.80 cents, and St. Louis 3.67½ at 3.72½.

Tin.—This market has declined. Speculators on the London market raised the price for a time, but buyers were disinterested, and the market weakened. December tin in this market is about 32½ cents.

Spelter.—Early in December foreign orders for this metal caused prices to rise sharply. A large business has been done in exports and there is prospect of a continuance of a firm market. New York spelter is quoted at 5.65 cents, and St. Louis at 5.50.

Other Metals.—Business in aluminium has been slow and the volume of sales small. New York quotation is about 19 cents per pound for No. 1 ingots. Antimony prices are weaker in view of weaker demand, and various brands are quoted at from 13 to 16½ cents. The quicksilver market is quiet, with little change in prices. Flasks of 75 lb. are quoted at $52.50.

The Iron and Steel Market

The turn has occurred in the steel trade. The improvement in sentiment that became noticeable early in November has been followed in December by a buying movement which is by no means of spectacular proportions but which nevertheless represents a radical turn from conditions of recent months. In sheets and tin plates the actual shipping orders booked in December have been nearly double those of November. In bars, plates and shapes the increases have averaged 50 per cent or more, while in tubular goods and wire products there have been slight increases.

In most commodities the trend of prices is distinctly upwards. Throughout December the mills quoted 1.05c. on bars, plates and shapes for immediate specification and 1.10c. on contracts involving specification during the first quarter, and at the close of December there was a general withdrawal of the 1.05c. quotation. In wire products there are predictions of an early advance. In the sheet market prices have continued irregular, but have not declined further in the past week or two, and a stiffening in quotations is not improbable in the near future.

The Year's Results

The average level of prices in the finished steel trade in 1914 was the lowest for any year since 1898, when conditions were altogether different. In pig iron prices have averaged the lowest in recent years, but have not been as low as in 1904.

The production of pig iron in 1914 was about 23,200,000 gross tons, representing a decrease of 25 per cent. from 1913, the banner year. The decrease in steel ingots was greater and in finished steel products still greater, as some stocks of pig iron have been accumulated, and also at some plants there has been a little accumulation of ingots.

The smallness of profits in the year is illustrated by the fact that the United States Steel Corporation's earnings will fall between $70,000,000 and $80,000,000, the only year in its history showing earnings approximately as small being 1904, when the corporation's productive capacity was much smaller than at present.

Pig Iron

The pig iron buying in the Buffalo district late in November was followed by buying of importance in most other districts. The sales by Buffalo furnaces aggregated fully 200,000 tons, and the movement in the Pittsburgh district, somewhat later, involved about 125,000 tons. The Chicago district moved 100,000 tons or more. The movement in southern iron was not in keeping with that in northern, for instead of southern iron leading, as usual, the buying occurred later, and the volume was not large, perhaps 250,000 tons. While the pig iron buying movement as a whole did not by any means reach the proportions of some movements in the past, it represented the greatest concentrated activity for about a year. In some districts there was an apparent yielding in price, but this was simply the replacement of a nominal market by a real market. In the Pittsburgh district there was no change, while at Buffalo and Chicago there were advances after the iron had been sold. The market is now moderately active and prices are quotable as follows: No. 2 foundry, Birmingham, $9.50 to $9.75; delivered Philadelphia, $14.25; f.o.b. furnace, Buffalo, $13; f.o.b. furnace, Chicago, $13; at valley furnaces (95 cents higher delivered Pittsburgh): Bessemer, $13.75; basic, $12.50; No. 2 foundry and malleable, $12.75 to $13; gray forge, $12.50 to $12.75. Ferromanganese is nominally quoted at $68, Baltimore.

Steel

The market for billets and sheet bars is not closely quotable, as most transactions are really in the nature of price adjustments upon long term contracts. There have been offerings for prompt shipment at $18.50 for billets and $19 for sheet bars, at maker's mill, Youngstown, but for delivery over the quarter quotations are about 50c. a ton higher. The Pittsburgh producers are quoting about 50c. a ton higher at mill than the lowest Youngstown sellers.

Finished Steel

Prices quoted below are for contracts over two or three months. In some commodities lower prices for immediate shipment have been ruling, but these are largely withdrawn. Prices quoted are f.o.b. Pittsburgh, unless otherwise stated, but on many products the Chicago and eastern Pennsylvania mills are quoting lower delivered prices in their territories than the equivalent Pittsburgh prices plus freight.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill except Colorado.

Plates, tank quality, 1.10c.

Shapes, 1.10c.

Steel bars and bands, 1.10c.; hoops, 1.25c.

Refined iron bars, 1.20c., Pittsburgh; common iron bars, 1.12½c., Philadelphia; .95c., Chicago.

Sheets, blue annealed, 10 gage, 1.30c.; black, 28 gage, 1.85c.; galvanized, 28 gage, 2.80c.; painted corrugated,

28 gage, 2.05c.; galvanized corrugated, 28 gage, 2.85c.

Tin plate, season price announced Dec. 3, $3.20 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., 81 per cent off list.

Steel boiler tubes, 3½ to 4½ in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Cold rolled shafting, 67 per cent off list.

Chain, ⅜ in. proof coil, 3.00c.

"The Little Journal" is the name of a new paper to be published "occasionally" by Arthur D. Little, Inc., chemists, engineers, managers, of Boston, Mass. The catchy name puts at once the reader into good humor, and creates high expectations. These are not disappointed. The contents are worthy of the name Little and what it stands for in American chemistry. There is no smack of amateurishness in this Vol. I, No. 1. Its editorial finish is really remarkable. An article on "raw materials and the war" sketches concisely how the supply of various metals, chemicals, drugs and dyes has been affected by the war. "Dyestuffs," "Radium in America," "Nitrocellulose in War and Peace" are the subjects of further articles, Ernest Solvay and Alfred Nobel the subjects of biographical notes. There are three brief editorials. In the first the cry for an immediate creation of an independent American dyestuff industry is amusingly ridiculed by the proposal to utilize American rainbows. The other two editorials refer to inevitable consequences of the war for the European nations. "European industry will be on a new basis when the war is over," because the overhead charges will be higher, "and costs of production will more nearly approach our own." As to the loss to science due to the war, "the loss to science and the world would have been no less disastrous though unappreciated had Faraday and Curie and Solvay and Helmholtz and Mendeleef fallen on the firing line at twenty-one." We extend to "The Little Journal" our cordial wishes for a long and glorious career.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in September, 1914, was 60. The total quantity of ore milled during that period was 2,242,913 tons. There were 9795 stamps in operation with an average duty of 8.86 tons per 24 hours. Tube mills in commission numbered 292. The yield for the month was 702,170 fine ounces gold.

Bolivian mineral exports, according to American Minister John D. O'Rear, at La Paz, are mainly in the form of high-grade concentrates. There are no smelters in the country. The following table shows in kilos (1 kilo = 2.2046 lb.) the exports of the principal minerals for the last few years:

Minerals	1908 Kilos.	1909 Kilos.
Tin	29,938,282	35,566,415
Silver	156,482	155,360
Copper	2,877,605	3,096,605
Bismuth	160,304	236,762
Wolfram	169,637	152,600
Zinc	1,242	602,000
Lead	5,150	7,000
Antimony	919,735	494,440
Gold	35	42
Total	34,228,472	40,311,224

Exports for the first eight months of 1914, reported in kilos, were: Tin, 26,021,564; silver, 12,624,754; copper, 202,265; bismuth, 163,520; wolfram, 145,780; antimony, 120,770.

"Ironised" Steel Tubes.—From a note in the London *Electrician* of November 20, 1914, we learn that noncorrosive steel tubes will soon be on the market, as the British Mannesmann Tube Co. (Ltd.) have just completed a plant for ferro-zincing and ironizing tubes, under license from Mr. S. Cowper-Coles. "It is a well-known fact that the purer the iron the less liable it is to pitting and corrosion, chemically pure iron being practically rustless. 'Ferro-zincing' or 'ironizing' turns these facts to account by coating the steel surface with almost pure iron, the only impurity of any significance being hydrogen. The addition of hydrogen is an advantage, for the reason that it makes the iron slightly more electropositive to the underlying steel than it would otherwise be, so that it forms a better protective coating. Another advantage of the coating of electrolytic iron is that the coating is homogeneous, and is not under unequal strain caused by mechanical operations, such as drawing or hammering, and has not been subjected to any heat or mechanical treatment which, of necessity, caused impurities to be absorbed by the metal so treated. It is advantageous for many purposes to coat the electrolytic iron surface with zinc, as a zinc coating with an intermediate layer of pure iron-hydrogen alloy gives a greatly increased life to an ordinary steel tube or plate."

Operating Data on Copper Smelting Furnaces.—The following data, taken from "The Copper Smelting Industries of Canada," a bulletin issued by the Canadian Department of Mines, gives the principal data regarding the operation of the furnaces of the British Columbia Copper Co., Greenwood, B. C. There are three water-jacketed blast furnaces. Originally these furnaces were 48 in. by 240 in. at the tuyeres; the capacity was recently increased about one-third by widening the two end furnaces to 51 in. and lengthening them to 360 in.

Charge, tons per sq. ft. hearth area, 24 hr.	6.2
Per cent copper on charge	0.8-1.2
Per cent sulphur on charge	1.6-3.5
Per cent sulphur burnt off	80.0
Per cent coke on charge	12-14
Per cent ash in coke	22-25
Blast, cu. ft. per min.	25,000
Blast temperature	Atmospheric
Cooling water for jackets, gal. per hr. 3 furnaces	4,000
Men in 8-hr. shift	20
Matte, per cent of charge	2.0
Matte, per cent of copper	40.0
Matte, sp. gr.	5
Slag, per cent SiO_2	43 -46
Slag, per cent Fe(Mn)O	19 -27
Slag, per cent Ca(Mg)O	21 -28
Slag, per cent Al_2O_3	6 - 9
Slag, per cent Cu	0.2- 0.25
Slag, per cent sp. gr.	3.2

The Nipissing Company, of Cobalt, Canada, has been making no shipments of silver bullion for several weeks. As a consequence the silver shipments from Cobalt have been below the normal. On the 10th of November the shipments from the O'Brien and Dominion Reduction were valued at $48,243.

Nevada's mineral production for 1913 has been valued by the U. S. Geological Survey at $37,842,084, as against $39,111,828 in 1912.

1910 Kilos.	1911 Kilos.	1912 Kilos.	1913 Kilos.
38,548,441	37,073,148	38,614,228	44,594,749
142,977	127,990	123,939	81,289
3,211,987	2,950,023	4,707,188	4,019,635
311,060	414,598	477,748	422,664
210,061	297,272	474,640	282,577
11,897,000	9,795,125	8,961,352	7,367,463
30,485	313,188	1,071,887	1,763,206
524,878	311,715	91,350	.....
.....	55	78	93
54,876,889	51,316,114	54,525,410	58,531,676

The Boss mine, in the Yellow Pine mining district, Clark county, Nevada, in which platinum has been found, is reported to have been sold for $250,000. Another discovery of platinum ore in the same district is reported from the Aura Amigo mine.

The nitrate industry of Chile is reported seriously affected by world conditions. Small towns have become almost depopulated, commerce is at a stand-

still and financial conditions are unfavorable. The Chilean government has advanced about $1,396,000 to companies that have applied for assistance. Consul D. J. D. Myers of Iquique, Chile, believes, however, that American manufacturers can secure business when normal conditions are resumed.

The Aurora mill in Nevada has adopted trays in Dorr thickeners to increase settling capacity.

The new mill of the Alaska Gold Mines Co. will present a new departure in gold milling. The ore will be coarsely broken with jaw crushers and gyratories, followed by two series of rolls. This will reduce the ore to a degree of fineness appropriate for rough concentration. The next step will be grinding in pebble mills, followed by the usual methods of concentration and amalgamation. The most radical departure from customary practice is in the abandonment of stamps and the adoption of methods heretofore applied to the porphyry copper ores.

Copper Blast Furnaces and Converters in Canada

There are 29 rectangular water-jacketed copper blast furnaces in Canada at the present time, the majority of which have been in active operation up to the opening of the European war. The total hearth area of these furnaces is 2,580 sq. ft. and the total rated capacity is 15,600 tons in 24 hours. The actual duty varies considerably at the different plants, on account of the differences in ore treated. The following table, taken from Bulletin 209 of the Canadian Department of Mines, prepared by Alfred W. G. Wilson, gives the principal data:

Company	No. of furnaces	Tuyere dimensions	Hearth area in sq. ft.	Ore column, ft.	Approx. rated capacity, short tons
Canadian Copper Co.	5	50x204	70.83	14	400
	1	50x240	83.33	14	550
Mond Nickel Co.	2	50x240	83.33	12	550
Cons. Min. & Smelt. Co.	1	42x210	61.25	8	350
	1	42x360	105.00	8	650
	1	42x264	77.00	8	460
	1	42x420	122.50	8	700
	1	50x420	145.80	8	875
Granby Cons. Mining & Smelting Co. Grand Forks	6	44x266.5	81.41	12	500
	2	48x260	86.67	12	550
Anyox	3	50x360	125.00	12	750
B. C. Copper Co.	2	51x360	127.50	12	800
	1	51x240	85.00	12	500
Tyee Copper Co.	1	42x120	35.00	6	200
	1	48x160	53.33	6	300

Five out of the seven copper smelting plants in Canada are equipped with converters. The following tabulation gives the principal data:

Company	Type	Stands	Shells	Dimensions
Canadian Copper Co.	Basic. Pierce - Smith Special	5	5	10′ 0″x37′ 2″
Mond Nickel Co.	Basic. Pierce - Smith Standard	2	2	10′ 0″x25′ 10″
Granby Cons. M. & S. Co.: Grand Forks	Basic. Power & Mining Mchy Co. Acid shells	3	10	84″x126″
Anyox	Basic. Great Falls type	3	3	12′ 0″x5′ 9″
B. C. Copper Co.	Acid. Allis-Chalmers	2	5	84″x126″

The Dome Mines Co., Porcupine, Canada, milled the largest tonnage in its history during October, treating 22,500 tons of $4.70 ore.

Ray Consolidated Copper Co. has advised stockholders that the directors have deemed it wise to defer payment of the quarterly dividend which would have been declared payable on December 31, 1914.

A tin concentrating mill recently erected at the Leeuwpoort mine in the Transvaal, is said by the *South African Mining Journal* to represent "the last word in tin mining equipment in this country," if not in the world. The plant contains Californian and Nissen stamps, Harz jigs, Richards-Janney classifiers, Buss and Wilfley tables, Isbell vanners and Dorr thickeners—a line of concentrating machinery that will have quite a familiar sound to every American millman.

Gold deposits in the assay office of the United States at Seattle, Wash., during the fiscal year ended June 30, 1913, as reported by the Director of the Mint, amounted to 239,557,528 fine ounces, valued at $5,006,750.25. Of this amount Alaska contributed 173,228,343 fine ounces. The total deposits in this office since its establishment July 15, 1898, to the close of business June 30, 1913, amounted to 12,294,-202.83 fine ounces gold, having a coining value of $211,363,034.76, of which Alaska contributed $106,-248,265.09.

Platinum, palladium and osmiridium are recovered as by-products of refineries in the United States Mints. The following table shows these recoveries for the fiscal year ended June 30, 1913:

	Sponge platinum		Sponge palladium		Osmiridium	
San Francisco	205.74	$895.99	...	.....	0.35	$1,400
Denver	58.20	2,328.00	10.15	$406.00	...	.....
New York	1,403.00	59,712.09	18.10	760.20	...	.....
	1,666.94	$62,936.08	28.25	$1,166.20	0.35	$1,400

Mill Tailings for Road Metal.—In Missouri a considerable amount of road material is obtained from the tailings of the concentrating mills at the zinc mines. This material, which is put on the market as "chats," consists of small angular fragments of chert and limestone. The zinc companies are very glad to get rid of this waste material, which is loaded on the cars by the railroads of the district at a cost of about 6 or 8 cents a ton. It makes more than ordinarily good roads and is widely distributed all through the Middle West. It sells in most places at prices ranging from 50 cents to $1 a ton, but in the neighborhood of the mines it can be had for about 15 cents a ton. It is used for railroad ballast as well as road making. The annual output, according to the United States Geological Survey, amounts to not less than 1,300,000 tons.

The Nevada Cinnabar Co., operating at Ione, Nevada, is reported to have shipped several carloads of flasks of quicksilver to the New York market. The furnace is producing from 20 to 25 flasks of metal daily.

Labor Conditions at Butte.—Labor disturbances at Butte have assumed a new phase: dissension exists within the labor unions, and not between companies and unions. Butte is a copper mining district, and as copper production is affected by the European war, the possibilities of a labor shortage at this time have no terror for the companies. In fact they have taken a radical step in declaring for the open shop in Butte, and hereafter the possession of a union card will not be a prerequisite for holding a job, nor will union representatives be permitted to visit the mines to inspect such cards. Butte has long been a stronghold of unionism and the companies have always dealt with unions, but contending union factions have brought about their own downfall.

Ignition of Gas by Fracture of Small Lamp Bulbs.—In a paper read by Mr. E. A. Hailwood at a recent meeting of the Midland Institute of Mining, Civil and Mechanical Engineers, at Leeds, the author declared that the commonly accepted opinion that it was not possible to ignite gas by the breaking of a small electric lamp bulb was entirely erroneous, and that he had in his experiments produced hundreds of ignitions by that means. He thought that such ignition might possibly be explained by the gas which rushed in to fill the destroyed vacuum being momentarily compressed against the red-hot filament with consequent explosion. He doubted whether the insertion of a fuse would be a remedy. The lamps in question were about 1 to 1½ cp.

An Electric Muffle Furnace for the Determination of Carbon and Oxygen in Steel and Tungsten Powder

BY CHARLES MORRIS JOHNSON

In 1908, the writer introduced the determination of carbon in iron, steel, etc., by means of the direct ignition with oxygen in an electrically heated furnace. (*Journal*, Am. Chem. Soc., Vol. XXX, No. 5.) Several months ago, he designed a muffle furnace for this purpose which has so many advantages over the original model that he is replacing the twelve furnaces of the old form with this new muffle type in the Park Works laboratory of the Crucible Steel Company of America.

The illustration shows the simplicity of construction. The furnace in the foreground of the picture and containing the tapered clay combustion tube (see Analysis of Special Steels, page 244, for a description of this tube) consists of a split cylindrical muffle of special non-heat conducting composition, of a hoop iron frame, and the nichrome heating element embedded in refractory cement. This heating element is to be seen in the cut, lying on the table in a half muffle. The wire is *not* wrapped around an inner core tube but is covered with the cement and dried on a form. Drying on a form was originated by Mr. I. A. Nicholas for such work.

The four furnaces connected in trains of apparatus show the modification that the author uses for the determination of oxygen. If it is desired to cool these furnaces rapidly, the current is shut off and the top half of the muffle is removed. Those desiring further details of the oxygen method should consult pages 74 to 82 of "Special Steels."

ELECTRIC MUFFLE FURNACE FOR STEEL LABORATORY

The advantages of this muffle furnace construction are: Very low first cost, ease of repair, quick heating and quick cooling. The furnace on a 220-volt direct current will heat from the cold to 1000 deg. C. in from fifteen to twenty minutes! It also presents a cleaner and much brighter appearance than the older style which has a case of black iron. It is easily kept clean and cheerful looking by an occasional dusting, together with the application of some fine-grained sandpaper.

Being of acid-proof material, the muffle is, of course, unaffected by fumes. There are no screws or insulating powder to bother with when the heating element has to be renewed. The later merely is slipped into place.

The following figures give an idea of how cheaply one can build such a furnace:

One split muffle	$2.00
One hoop-iron frame	2.00
Flexible cord and connections	1.50
Heating element	4.50

If the heating element is prepared in the laboratory and the frame support is made by the smith in the works, the above cost can be reduced several dollars.

Pittsburgh, Pa.

Apparatus for the Concentration of Sulphuric Acid

BY WILLIAM MASON

The concentration of sulphuric acid simply means the separation of the acid from water by the process of evaporation. The sulphuric acid as it issues from the chamber system is usually of a specific gravity of 1.560, containing 65.27 per cent of sulphuric acid, and is evaporated until it attains the specific gravity of 1.840 or contains about 96 per cent of sulphuric acid. The weak acid begins to lose water at about 122 deg. Fahr. and boils at 305 deg. Fahr. The strong acid boils at 563 deg. Fahr.; but it is known that this sulphuric acid may be concentrated at a temperature much below its boiling point, namely, at a temperature of about 450 deg. Fahr.

The construction of apparatus for the concentration of sulphuric acid has, at times, had considerable attention. Many forms of apparatus have been invented, and many metals have been used in their construction from brittle glass to the expensive metals of gold and platinum. Of late years apparatus have been built of volcanic lava, but these, it will easily be seen, are very expensive, costing as much at £1,500 ($7,500). It is a fact that although some of these apparatus produced acid much cheaper, requiring less fuel and reducing the cost of labor, they very rarely produced it equal in color to that which was produced by the old-fashioned glass retorts; and, for this reason, the glass retorts are found working in some works to-day.

In the year 1890, Negrier introduced what is known as the capsule system of construction which was further improved upon by Benker. It is an attempt to evaporate fractionally. This form of apparatus has had a very varied career. In the first plant porcelain capsules were used, and it may be that, from the fragile nature of this material, it was not persevered with. However, with the invention of a fused silica material for this purpose, this form of apparatus has again appeared, and plants of the capsule type have been erected in many places, again with varied results. Some

TABLE I. SPECIFICATION FOR PLANT FOR 4 TONS PER 24 HOURS

	£	*s.*	*d.*
Fused silica basins, delivery pipes and coolers	43	8	
Acid-proof tiles, 1000 acid-proof bricks and cement for same	13	15	
10,000 ordinary bricks, including 500 arch bricks and concrete	27	10	
6000 fire bricks of various sizes	16		
H wrought iron girders and wrought iron stays	11	12	
Cost of furnace and accessories	7		
6 lead pans, lead vessels for silica coolers, lead vessels for worm type coolers, materials and labor	41	10	
Iron plates for supporting lead pans	5	5	
Wood centers for arches, asbestos cord for seating capsules and sundries	3	10	
Materials and labor for condenser for exit gases, with connections	57	10	
Cost of labor for erecting plant	30		
TOTAL	265		

TABLE II. COST OF PRODUCTION OF 1 TON

	s.	*d*
Fuel, coals, 2 cwts. at 8 *s.* 4 *d.* per ton; fuel, coke breeze, 1 cwt., 2 qr. at 4 *s.* 6 *d.* per ton	1	2½
Wages	2	
General expenses	3	2
	6	4½

TABLE III

	%		%		%
Lead pan No. 1		Capsule No. 1	78.84	Capsule No. 13	87.16
" " " 2		" " 5	79.90	" " 14	88.21
" " " 3	65.25	" " 6	80.83	" " 15	89.12
" " " 4	65.25	" " 7	81.47	" " 16	91.08
" " " 5	72.0	" " 8	82.5	" " 17	92.0
" " " 6	74.0	" " 9	83.36	" " 18	93.08
Capsule No. 1	75.25	" " 10	84.42	" " 19	94.37
" " 2	76.0	" " 11	85.34	" " 20	95.25
" " 3	77.66	" " 12	86.23		

firms, after several trials and experiments with furnaces of varied construction have discarded them, preferring the type of apparatus in which the sulphuric acid is concentrated by contact with the furnace gases; but this type of apparatus does not produce an acid as clear as that which is made by the capsule or glass retort systems.

The author, having had several years' practical experience with a capsule plant, gives in the accompanying drawing a description of a plant which gives most satisfactory results. Fig. 1 is a plan, Fig. 2 is a sectional elevation, Fig. 3 a section through *EF*, Fig. 4 a section through *LM*, Fig. 5 a section through *GH*, Fig. 6 a section through *JK*.

Table I (p. 17) is also a specification of the cost of a plant to produce 4 tons of sulphuric acid in twenty-four hours.

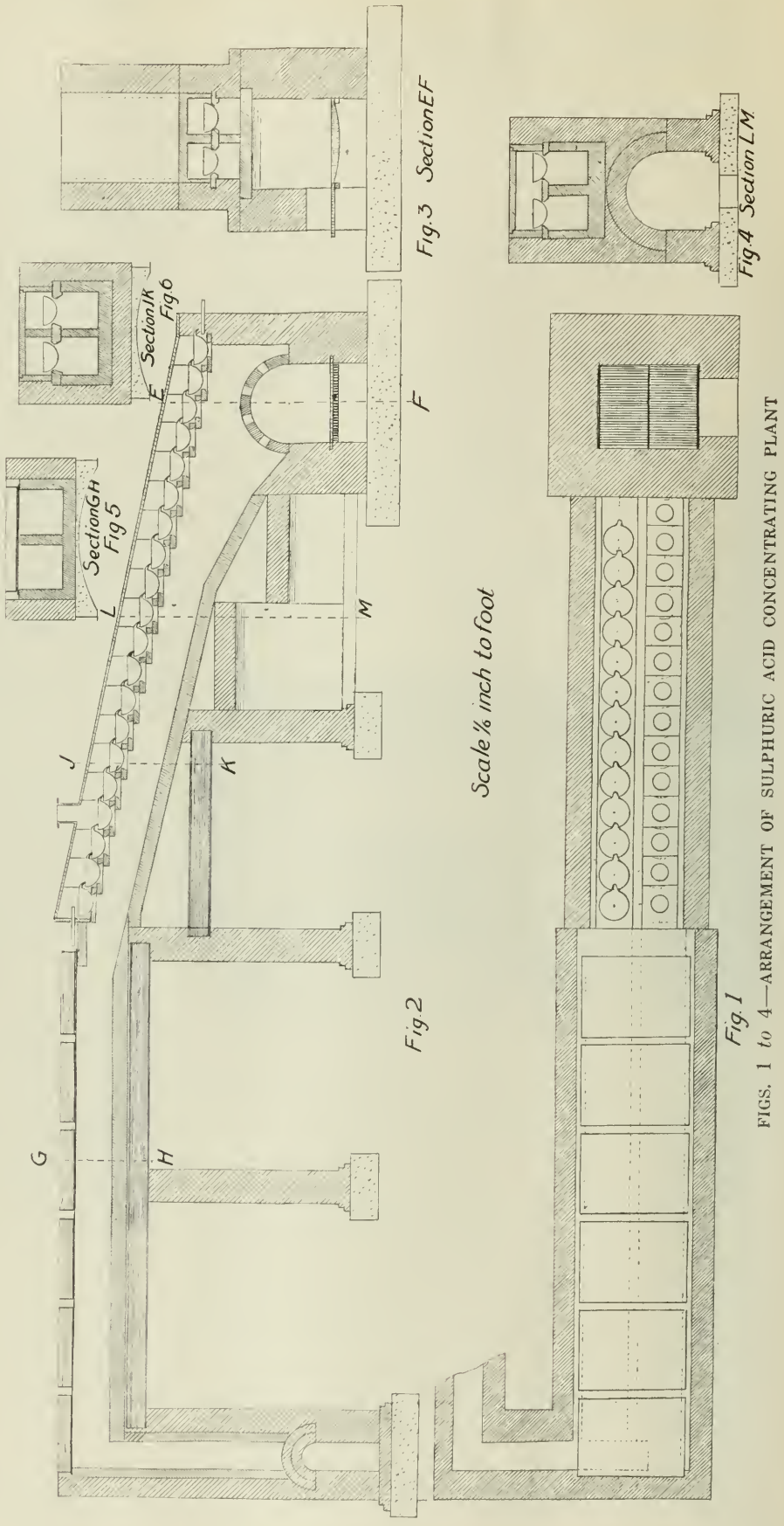
The cost of producing 1 ton of sulphuric acid by this plant was as given in Table II.

The working of this plant shows that the concentration of the sulphuric acid proceeds as stated in Table III.

The weak acid recovered by condensing the exit-gases was of a specific gravity 1.240 and was equal to 2.23 per cent of the weight of the acid produced. In the glass retort system the acid in the weak acid was usually equal to about 15.0 per cent of the acid produced.

The great drawback in constructing this type of apparatus has been that of using a forced-draught furnace. Such a furnace gives too high a temperature in the lower part of the plant, which causes much bumping of the capsules. In this way most of the capsules have been broken. An ordinary furnace with careful and regular working of same will produce economically a very colorless acid of satisfactory strength.

Oxford, England.



FIGS. 1 to 4—ARRANGEMENT OF SULPHURIC ACID CONCENTRATING PLANT

Quicksilver producers in the United States now have an opportunity to capture the trade with Central and South America and with the Orient from Japan to India, according to a statement by the U. S. Geological Survey. Austrian production, controlled by the government, is cut off from the world market; Italian supplies are considered uncertain; and the Spanish output is controlled in London and probably is not available for foreign trade. Domestic prices for quicksilver had been ranging from $39 to $37.50 per flask of 75 lb. until the war broke out, when they rose rapidly to from $75 to $90 per flask. The price has since receded to about $55. The Nevada Cinnabar Co., operating at Ione, Nev., is reported to have recently commenced production at the rate of sixty flasks per week.

Refractometry

BY G. A. SHOOK.

III.—Measurement of Refractive Index and Dispersion

As was pointed out in the first article of this series, it is more logical always to express the refraction of any substance in terms of the refractive index for sodium light than in terms of the scale divisions of some particular instrument.

Nevertheless it is manifestly more convenient in certain classes of analysis to express the refraction in terms of an arbitrary number. For example, it is somewhat simpler to designate the refraction of olive oil as 60.2 scale divisions (Butyro Refractometer) rather than in terms of the index for sodium light, namely 1.4660 and since adequate tables are accessible for converting the scale divisions of any arbitrarily graduated instrument into refractive indices—an arbitrary scale is really not objectionable.

Again in the case of an instrument like the Pulfrich refractometer which reads in circular degrees it is necessary to use a table and if the latter is properly constructed the index can very easily be obtained. Other things being equal it is, to be sure, advantageous to have the instrument graduated in refractive indices, but it is not always advantageous to sacrifice accuracy for convenience. On the Zeiss immersion refractometer scale, for example, one scale division corresponds to an increment in the index of about 0.0004 and by means of a vernier a tenth of a scale division can be accurately read, but in the Abbé instrument the fourth decimal place must be estimated. Therefore while the Abbé instrument gives the index directly and while its range is much greater than that of the Zeiss, it is not nearly so accurate.

The Féry instrument, however, has a wide range, but at the same time possesses an accuracy somewhat greater than that of the Abbé.

In the case of a comparatively simple instrument like the Butyro-refractometer, no special directions need be given for its manipulation but with a more complicated instrument like the Pulfrich refractometer it is quite different.

The method of manipulating two of the more complete instruments will now be considered in detail.

Manipulation of the Pulfrich Refractometer

This instrument is used primarily for research work, but it could undoubtedly be adapted for many kinds of commercial analysis.

As a research instrument it possesses many advantages over all the other types of refractometers. It is usually provided with two or three prisms of different refractive powers so that it may be used for practically all ranges. One is also able to measure, not only the index for sodium light but also the index for the *C*, *F*, and *G'* lines. Moreover the mean dispersion $n_F - n_C$, and the partial dispersions $n_D - n_C$, $n_F - n_D$, etc., may be determined. Finally an accuracy is here attainable which is greater than that of any other instrument of its range with the possible exception of the Féry refractometer.

For commercial work it has first of all the advantage of accuracy. Moreover, it is provided with a double cell so that the index of any liquid, say cottonseed oil, may be determined by comparing it with a standard oil. It is only necessary in this case to measure the difference between the two indices, and such a measurement can be made with greater precision than is possible in the measurement of the index. Moreover, since the variation of temperature will be practically the same for the standard and for the unknown oil, the measurement may be made at any temperature whatever.

The oléoréfractomètre of Amagat and Jean utilizes the same principle. This is an excellent instrument, but it is practically unknown in this country.

On the other hand, it is not quite so easy to make a rapid examination of a large number of samples with the Pulfrich instrument as with the Butyro refractometer or Abbé refractometer, for it is more difficult to clean the cell of the Pulfrich refractometer than the face of either the Abbé or the Butyro refractometer double prism. Again, the measurement of the index for the *C*, *F* and *G'* line is carried out by means of a hydrogen tube which is actuated by a small induction coil, and the latter is always a source of trouble.

For industrial use the hydrogen tube should be replaced by a commercial mercury lamp or some similar sort of monochromatic illuminator that can be run on any 110-volt alternating-current circuit.

For a red line a salt of lithium might be volatilized in the flame of a Merker burner just as we produce sodium light from fused sodium chloride. For a green line a thallium salt might be used. The tables furnished with the instrument would not, of course, be applicable if other lines than the *C*, *F* and *G'* were utilized.

There are numerous devices for controlling the temperature of the refractometer prism, but the one now generally sent out with this instrument is perhaps the most satisfactory.

Since the index of an oil is decreased by 0.000365 for each degree rise of temperature, it is essential to maintain the temperature of the cell within a few tenths of a degree.

Adjustment of the Pulfrich Refractometer

To adjust the hydrogen tube, *H* Fig. 1, fill the cell *C*

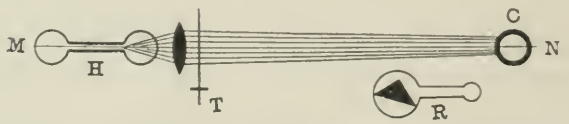


FIG. 1—DIAGRAMMATIC VIEW OF THE PULFRICH REFRACTOMETER

with any liquid (water will do) and turn the reflecting prism *R* out of the path of the rays from the tube *H*. By reference to the tables, furnished with the apparatus, for the particular prism, estimate roughly the position of the *C* line and then turn the telescope to this position so that when the cell is properly illuminated the *C* line will appear in the field of view.

With the current passing through the tube adjust the latter so as to produce the best illumination. Considerable care may be required to make this adjustment, for if the axis of the capillary tube is not in line with the optical axis of the instrument *M N*, the brightness of the lines is seriously impaired.

The cross wires in the telescope are always set on the upper edge of the line and not on the lower. By means of a shutter *T* the light coming from the upper half of the collimating lens may be cut off. By cutting out all of the extraneous light with this shutter the lines are rendered more distinct. If the entire aperture of the lens is exposed, they become ill-defined and an accurate setting is made impossible.

The *C* line is bright red and with most liquids sharp on the upper edge. The *F* line is blue-green and it is difficult to distinguish it from the other green lines that lie between it and the *C* line. The *G'* line is very faint and difficult to work with. Even the *F* line cannot be seen in the case of a liquid like butter.

If the tube happens to contain impurities such as mercury, water vapor, etc., other lines will be present

which may obscure the *C*, *F* and *G'* lines or at least confuse the observer as to which is the *F* or *G'* line, as the case may be.

The quickest way of identifying the *F* line is to take the index of water for the *F* line, which at room temperature is about 1.338, and determine from the tables the angle at which the telescope should be set so that the cross wires will be just about on this line. By turning the telescope to this position the line may be easily identified.

Before making any measurements it is necessary to make certain that when the telescope is in the position to receive the rays leaving the refractometer prism normally the reading on the circular scale is zero. This normal position is determined by means of an eye-piece of special construction.

A portion of the cross wires *W*, Fig. 2, in the focal plane of the telescope, is intercepted by a reflecting

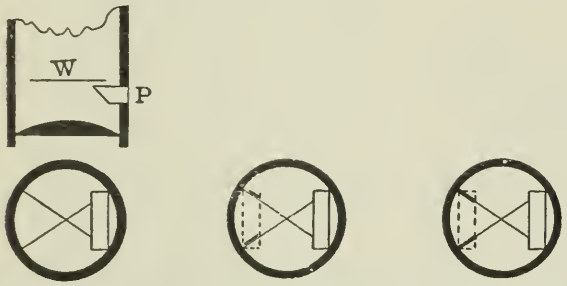


FIG. 2—CROSS WIRES OF THE PULFRICH REFRACTOMETER TELESCOPE

prism *P*. If light is admitted to this prism by placing the apparatus near a well-lighted window or by simply holding a light near the eye-piece (to the right of the observer), an image of that part of the cross wires which is cut out by the prism *P* will be formed on the opposite side of the field of view as shown by the second diagram.

This image is due to the light which is transmitted down the telescope and reflected back again by the vertical face of the refractometer prism. Consequently, if the incident beam strikes the prism surface normally it will be reflected normally, and therefore the image of the wires will coincide with the wires themselves as shown in the third diagram of Fig. 2.

The telescope should be rotated until this condition of coincidence obtains and then the reading of the circle should be noted. If it does not read zero, a correction should thereafter be applied.

The support carrying the prism and cell should always be clamped to the standard to which it belongs before making any measurements.

The circle *A*, Fig. 3, of the instrument reads to min-

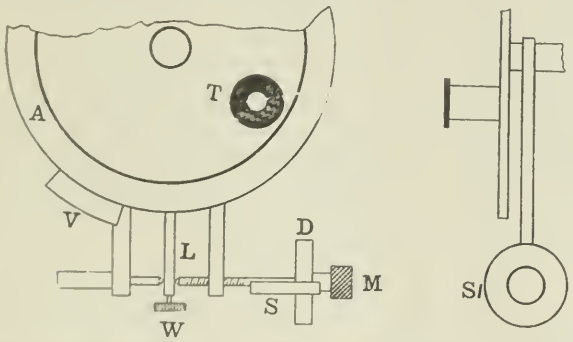


FIG. 3—MICROMETER OF THE PULFRICH REFRACTOMETER

utes by means of a verner *V*, but if a fraction of a minute is desired the micrometer *M* is used.

When the screw *W* is tightened, the circle is clamped rigidly to the lever *L*, and it can then only be rotated by means of the micrometer *M*. By means of *M* the circle, and consequently the telescope, may be turned through six degrees. The drum *D* is divided into 20 parts and each part represents one minute. The tenth part of a minute can be read directly from the drum and this is as close as one can set the cross wires under the most favorable circumstances.

This range of six degrees is long enough to measure the dispersion of any substance so that the circle need not be read for dispersion measurements after it is once adjusted and clamped by the screw *W*.

In the tables furnished with the instrument the index for the *D* line is given for every ten minutes, and the value for each minute must be determined by interpolation. For each of the ten minutes of angle a "correction," so called, is given to be applied to the *C*, *F* and *G'* lines. The method of obtaining data for the determination of the index for any line may be best illustrated by means of an example.

With water in the cell the angle for the *D* line, as read from the circle, was 67° 28′ and the micrometer read 2° 40′. For the *C* line the micrometer read 1° 49′, and for the *F* line 5° 13′. The angular difference for the *D* and *C* lines is therefore

$$2^\circ\ 40' - 1^\circ\ 49' = 51'$$

and consequently the angle corresponding to the *C* line is

$$67^\circ\ 28' - 51' = 66^\circ\ 37'.$$

In like manner the angular difference for the *F* and *D* lines is

$$5^\circ\ 13' - 2^\circ\ 40' = 2^\circ\ 33'$$

and the angle for the *F* line is

$$67^\circ\ 28' + 2^\circ\ 33' = 70^\circ\ 01'.$$

From the table, for the particular prism, the index for the *D* line corresponding to an angle of insidence equal to 67° 28′ is 1.33328.

For the angle 66° 37′ the index of refraction for the *D* line is, from the table, 1.33728, and the correction for the *C* line is — 596, whence the index for the *C* line is

$$1.33728 - 596 = 1.33132.$$

The n_d corresponding to the angle 70° 1′ is 1.32196 and the correction for the *F* line is + 1517, whence the index for the *F* line is 1.33713.

We finally have the following results:

$$n_c = 1.33132$$
$$n_d = 1.33328$$
$$n_f = 1.33713$$

and the mean dispersion is

$$n_f - n_c = 0.00581$$

Manifestly this computation is far too laborious to render the method applicable industrially. If a large number of observations are to be made it is decidedly advantageous to make out a table giving the index corresponding to the *C*, *D* and *F* lines for each degree. This table need include only values for the particular range in which the experimenter is working.

The writer, for example, made out such a table extending from 42° to 48°, and this range corresponds to a range of refractive indices from $n_d = 1.4417$ to $n_d = 1.4775$ for prism *I*b. This table is suitable for most of the edible oils. A portion of it is given in Table I.

TABLE 1—REFRACTIVE INDICES FOR PRISM Ib

Angle	D	C	F
42° 0′	1.4775	1.4721	1.4911
1	74	20	10
2	73	19	09
3	72	18	08
4	71	17	07
5	70	16	06
47° 57′	1.4420	1.4365	1.4559
58	19	64	58
59	18	63	57
60	17	62	56

Furthermore, since it is easier to read the micrometer than the vernier, of the circle, the former should always be used and it should be set so that some number on the micrometer corresponds to a particular number on the circle. The necessity for making a subtraction each time is thus obviated.

For the above table the circle was set at 45° and held there firmly. The screw *W* was then released and the micrometer was set at 2°. It is easy enough to remember that 2° on the micrometer scale *S* corresponds to 45° on the circle and that 1° corresponds to 44°, etc.

The angle can thus be easily read to one-tenth of a minute, if justifiable, and by means of such a table as is shown above the index for either the *D*, *C* or *F* line may be found directly.

While the index for sodium changes markedly with the temperature, the mean dispersion $n_F - n_C$ changes only slightly, indeed less than one part in the fourth decimal place for a temperature change of about 10° C. Therefore if the mean dispersion were measured at room temperatures a few degrees of fluctuation of the temperature would not affect its value and therefore the temperature would not have to be taken into account.

For some classes of work this constant might be as useful as the index for sodium light. The mean dispersions for a few oils are given in Table II.

TABLE II—MEAN DISPERSION OF EDIBLE OILS (45° C)

Oil	n_d	$n_f - n_c$
Cedar	1.50570	0.01031
Linseed	1.45928	0.01018
Castor	1.47027	0.00904
Cod liver	1.46984	0.00988
Lavender	1.46084	0.00953
Cottonseed	1.46394	0.00953
Hempseed	1.46889	0.00962
Rapeseed	1.46553	0.00933
Sesame	1.46429	0.00932
Olive	1.46040	0.00877
Butter	1.45296	0.00784
"	1.45246	0.00839
"	1.45226	0.00828
Cocoanut	1.44746	0.00739
Margarine	1.44606	0.00832

These values are taken from the recent work of Szalágyi.

The values of the mean dispersion for all liquids of commercial interest have never as yet been accurately determined and therefore can not be given.

With dark colored solutions it is difficult to make an accurate setting on the *F* (green-blue) line and therefore the mean dispersion in such cases can not be accurately determined unless a stronger light than that emitted by a hydrogen tube is available. With a high-power mercury lamp such a measurement could be easily carried out.

With transparent solutions, however, the mean dispersion can be determined to an accuracy of about two parts in the fifth decimal place.

Failure of the Refractometer to Detect Adulterants

While the refractometer may be successfully used to indicate the purity or the uniformity of a simple product like olive oil or natural butter, it may be easily demonstrated that it is practically useless for detecting the presence of a number of adulterants.

One often finds in reliable books on food analysis a statement to the effect that if the index of refraction (for some standard temperature) of a certain product, say, butter, does not exceed a particular value, the sample may be pronounced pure and chemical analysis may be dispensed with. Let us consider the following cases:

The limits of the index of refraction for natural butter at 25° C., according to Wollny, are 1.4590 to 1.4620. For most oils the index decreases by about 0.00037 for each degree rise in temperature so that for 35° C. the corresponding limits are approximately 1.4553 to 1.4583. Woolny suggests that, to remove all chances of adulterated butter escaping detection, the upper limit should be still lower at 35° C., about 1.4573.

A given sample of creamery butter examined by the writer gave an angular reading of 45° 35′ and the index for this angle, from his table, was found to be 1.4562, which is clearly within the limits of pure butter.

A sample of oleomargarine gave a reading of 1.4590, which is a little low, but not low enough, of course, to pass for butter.

For a cocoanut oil a value of 1.4498 was found for the index.

A mixture consisting of 2 cc. of oleomargarine and 1 cc. of cocoanut oil, upon examination gave a value of 1.4560 for the index, which is also within the limits of pure butter. Moreover, this mixture since its refraction is practically identical with the refraction of pure butter, could be used to adulterate butter to any degree whatever.

A second mixture consisting of 1 cc. of the first mixture (oleomargarine and cocoanut oil) and 1 cc. of butter gave for n_D a value of 1.4562. To be sure, there are other methods for determining the adulterants of butter, but it is evident from these examples that mixtures can be compounded which will render the refractometer useless.

Again, if the butter were low, a considerable amount of oleomargarine could be added before it reached the upper limit or if its index were high it might be adulterated with cocoanut oil.

Consider another example: A sample of olive oil gave a value of 1.4628 for n_d. At a temperature of 25° C. the limits for olive oil are 1.4660 to 1.4680 and for 35° C. about 1.4623 to 1.4643, so that this oil was within the limits, but had a rather low index. It was adulterated by adding an equal volume of cottonseed oil with the result that the index was increased to 1.4638, which is still within the limits.

The mean dispersion for this mixture was found to be 0.0090, but this difference in disperson is hardly great enough to pronounce the sample impure. If we had instruments for detecting smaller differences in the mean dispersions we might make use of this constant for detecting adulterants. However, it would not be difficult to produce a mixture which would not only possess the desired index but also at the same time any desired mean dispersion.

A second mixture consisting of 2 cc. of cottonseed oil and 1 cc. of cocoanut oil give for n_d a value of 1.4612 which is just below the lower limit. A smaller amount of cocoanut oil would bring the mixture within the limit. The mean dispersion in this case was 0.0086.

For a mixture of 2 cc. of lard oil and 1 cc. of cottonseed oil the index was found to be 1.4638. Varying amounts of this mixture could, of course, be added to olive oil as desired.

It is thus seen from the above examples that while an abnormally high or low refraction may be a sufficient characteristic of an adulterated product, it is most certainly not a necessary characteristic.

As far as the refractometer alone is concerned the unscrupulous manufacturer may easily deceive the analyst.

This is, however, only one of the many uses for the refractometer so that its value in chemical analysis must not be depreciated.

Manipulation of the Abbé Refractometer

The initial adjustment of the Abbé refractometer is now usually made in the following manner:

The telescope is rotated about the horizontal axis of the instrument until the plane of the upper prism is nearly horizontal, as shown in Fig. 4. A rectangular glass plate optically plane on one face and one end is

furnished with the instrument and its index for sodium light is 1.5176. A drop of monobromonaphthalene (n_d = 1.658) is placed on the prism face and the test plate is then placed on the prism. If the plate is held in place in any manner the instrument need not be rotated into this rather awkward position for making an observation.

It is necessary that the liquid between the two surfaces have a greater index of refraction than the plate, but the value of the index of the liquid is not used in any computation. The prism, by means of the alidade, many now be slightly rotated until the intersection of the cross wires coincides with the boundary or critical line. If the critical line is not colorless rotate the compensator until all color disappears. If the instrument now reads 1.5176 no further adjustment is necessary and it will read correctly throughout its entire scale.

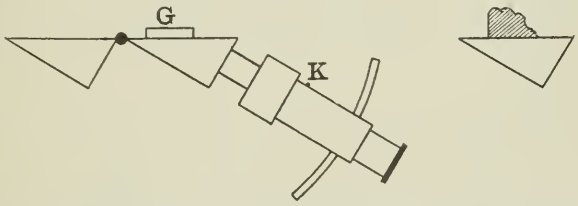


FIG. 4—EXAMINATION OF SOLIDS BY ABBE REFRACTOMETER

If, however, it does not indicate this value it can be made to do so by slightly shifting the cross wires. This is done by inserting a watch-key at *K*, Fig. 4, and turning the key until the critical line coincides with the intersection of the cross wires when the instrument is set at 1.5176.

Any transparent solid body, such as a piece of glass or quartz may be examined in a similar manner if it has two polished surfaces at right angles to each other as illustrated by the second diagram of Fig. 4.

The lower prism may be so tilted that the light reflected from the bright metal surface will enter the polished surface of the specimen normally. It is essential that the two polished surfaces intersect in a sharp edge since it is necessary that the light strikes the under surface of the specimen at grazing incidence.

From the reading of the compensator the dispersion can be estimated by means of a special table. This instrument, however, is not sensitive enough to detect small differences in the mean dispersion.

In Table III the readings of the compensator are given which were obtained for cottonseed, olive, and cocoanut oil:

TABLE III—READING OF THE ABBÉ COMPENSATOR

Oil	Scale Reading
Cottonseed	39.5
Olive	39.7
Cocoanut	40.1

The reading of the compensator for practically any liquid will fall somewhere between 39 and 41, and since the tenth part of a scale division must be estimated it is readily seen that such an instrument cannot be used for accurately determining the mean dispersion unless a very large number of observations are made. For such measurements an instrument of the Pulfrich type should be used.

University of Michigan,
Ann Arbor, Michigan.

The Santa Gertrudis Co., Ltd., reports that milling operations which were resumed on July 6, 1914, are continuing without interruption. Crushing is limited to about 85 per cent of the capacity, and it is not intended to increase this production until Mexican conditions become generally more settled and until a more certain supply of cyanide can be arranged.

Tube-Mill Tonnage Calculation

BY NOEL CUNNINGHAM

It is often difficult to determine the tonnage actually being handled by tube-mills working in closed circuit with classifiers. Where either tube-mill feed or discharge can be deflected and weighed for short periods it is still a quite inexact determination, as an accurate moisture sample is essential; and where a portion of the pulp is cut out of the flow and weighed, if the amount is sufficient to accurately determine the weight of total flow, it is next to impossible to get a close sample for moisture. In any case, only by averaging a number of weighings and moisture determinations can data of any value be obtained, and as it is an awkward, sloppy test it is not run often enough to be of real value.

The following method is, I believe, original with myself, and allows a close determination of tonnage from four screen tests which are often a part of either daily or periodic routine. The four samples required for these screen tests are: (a) Battery discharge, (b) tube-mill feed, (c) tube-mill discharge, and (d) classifier overflow.

The object of the calculation is to determine the ratio of dry tons tube-milled to dry battery tonnage. The calculation is based upon the fact that the minus 200-mesh material coming to the classifier is equal to the minus 200-mesh which leaves the classifier.

Let a = per cent minus 200-mesh in the battery discharge
b = per cent minus 200-mesh in the tube-mill feed
c = per cent minus 200-mesh in the tube-mill discharge
d = per cent minus 200-mesh in the classifier overflow
B = dry battery tonnage
T = dry tons tube-milled.

Now the minus 200-mesh material coming to the classifier is the sum of that in the battery discharge (aB) plus that in the tube-mill discharge (cT); while the minus 200-mesh material leaving the classifier is the sum of that in the tube-mill feed (bT) plus that in the classifier overflow (dB), hence:

$$aB + cT = bT + dB$$

and

$$\frac{T}{B} = \frac{d - a}{c - b}$$

= ratio dry tons tube-milled to dry battery tonnage.

Thus, knowing the dry tons passing through the battery daily, the dry tons actually tube-milled daily can be readily calculated from the routine screen tests.

It is interesting to study the limits of this ratio in practice. I should say in a general way that the minus 200-mesh in modern fine-grinding plants for the four screen tests entering into the above calculation would lie between the following limits:

	Per cent minus 200-mesh	
	Minimum	Maximum
Battery discharge	10	30
Tube-mill feed	2	8
Tube-mill discharge	35	60
Classifier overflow	60	90

The lowest value of $(d - a)$ within these limits would be 30 and the largest value of $(c - b)$ would be 58, hence within the above limits, tons tube-milled could never be less than half of battery tonnage. In the same way the highest value of $(d - a)$ within the limits above would be 80 and the lowest value of $(c - b)$ 27, or the maximum tonnage tube-milled within the above limits could not be over three times battery tonnage. Generalizing I should say that for mills where tonnage is being pushed, this ratio would be about 1.75 and never under 1.

New York City.

Comparisons of Electric Resistivities at High Temperatures

BY CARL HERING

Our knowledge of the electric resistivities of conductors at the higher temperatures, hence including those of molten metals, heated refractories, etc., is somewhat meager, although some important contributions have been made recently. In the design of those electric furnaces which are based on high-temperature resistance, these data are of considerable importance, both the absolute values of the resistivities and their comparisons. A comparative study of such resistivities might also lead to a discovery of some useful general physical law.

What meager data exists are greatly scattered in the literature; such values are sometimes given as conductivities, sometimes as resistivities, and often in entirely different units; sometimes the units are omitted entirely, this rendering the results nearly valueless. In some cases the mere resistance of a piece is given, without the necessary dimensions which would enable the resistivity (specific resistance) to be determined. In some cases true resistivities are given as "resistances," as in the French literature, for instance. Some of the data are given in curves, each with entirely different scales (for good reasons), in some cases different parts of one curve are even given in entirely different scales, even relatively different. The temperature coefficients are sometimes given in entirely different forms which in some cases are unintelligible; these coefficients and the abrupt changes during melting and vaporization are of importance as they cause some of the values to change relatively quite greatly at the higher temperatures.

A comparison of the different resistance materials, their ranges of temperature and their rates of change, both relative and absolute, therefore becomes tedious. Tabulated figures, even when well arranged, do not give the clear and direct mental picture that curves drawn to the same scale do; hence to facilitate such comparisons and to make their relative values more directly apparent, the writer has compiled what data he could find and has combined most of them in the uniform sets of curves given below, charts 1 to 5, in which all in each set have been reduced to the same scales. For more accurate values the original data should be consulted, though this is sometimes very crude, hence only roughly approximate.

When thus directly compared quantitatively, such curves show some interesting results. Moreover, as the relative values of the different materials often change very decidedly with increasing temperatures, curves are the only way to represent them directly and clearly; no tables, no matter how well arranged, could present the results so directly.

It is believed that this is the first attempt to make a compilation of this kind, and it is suggested that these charts be republished from time to time by this journal with amplifications, new data, and corrections from those who can contribute them.

The temperature scales are the same in all. Owing to the extremely wide range of resistivities, about 400,000,000, it is, of course, impossible to have them all on one chart. The scale of ordinates in each chart has been made twenty time that of the preceding one, except in the case of chart 3, in which the increase is 2500 times, there being few if any materials in that range, namely, between the metals which increase with temperature and the non-metallic materials which decrease; in general between 0.005 to 0.5 ohm. Solid graphite and carbon are more of the order of magnitude of the metals, hence are with the low-resistance materials, while silicon and powdered or granular graphite and carbon are nearer to the high-resistance group.

Some of the curves are duplicated on two successive charts so as to facilitate comparisons; but none could be carried over from chart 2 to 3 on account of the very wide range between them. The scale of chart 5 is just 1,000,000 times that of chart 1.

The observed values are shown in full lines; the dotted lines are exterpolated and should therefore be used with some reserve. It is believed that for pure metals at least all electrical resistance vanishes at absolute zero of temperature. Furthermore, recent determinations by several physicists indicate that the resistivities of some metals at least seem to increase linearly above their melting points. If these two laws, on which most of the exterpolations have here been based, are correct, the exterpolated values are probably not far wrong; and until actual determinations are made they will at least serve as probable approximations; moreover, until then they are the only data we have, and are therefore probably better than none. The writer, therefore, feels justified to make them here, even though they are not established data.

The termination of a curve with a small circle means that this is the maximum temperature at which these materials can be used, according to their makers. In the case of most of the liquid metals, their boiling points are shown by short vertical dotted lines, indicating a probable abrupt though unknown increase of resistivity; beyond their boiling points they are, of course, no longer available as liquid resistors. As metals usually go through an abrupt change of resistivity at their melting points, these latter are readily noticed on some of the curves. Both melting and boiling points are given numerically in the text in conjunction with the references. The melting points have been taken largely from the tables of the Bureau of Standards and the boiling points largely from the Smithsonian Physical Tables.

The resistivities in the text are here all given in microhm, centimeter cube units, unless otherwise stated. The conversion figures are:

resistivities in inch cube units = resistivities in cm cube units $\times$ 0.393700;

resistivities in cm cube units = resistivities in inch cube units $\times$ 2.54001.

Both co-ordinates of the present curves have been started at zero (the absolute zero, in the case of temperature), so as to facilitate direct comparisons and the finding of any general laws, if they exist.

References to most of the original sources of the data, where in some cases more detailed data may be obtained, are given below. The present writer, however, has supplemented these data with additional matter, deductions and comments, for which he assumes the responsibility.

The scale of Fahrenheit degrees is given at the top of each chart, and the scales for the values for 1-in. cube are given on the right-hand side.

For the temperature coefficient the usually adopted form is here used, namely, a in the formula $R = r(1 + at)$, in which R is the resistivity at $t°$ centigrade, r that at 0° C.; sometimes the latter is given at 20° C., in which cases 20 should be subtracted from t; but for the higher temperatures here dealt with this correction is of no importance. For the higher temperatures there is sometimes an additional factor $\pm bt^2$ in the parenthesis, but in most cases the values are not known with sufficient accuracy to warrant such refinement, hence this has in most cases been neglected here.

In some cases the curves, representing the changes with temperature, when more accurately drawn, are not quite straight lines; it may be possible that this is due to a change of volume due to expansion, or to a propor-

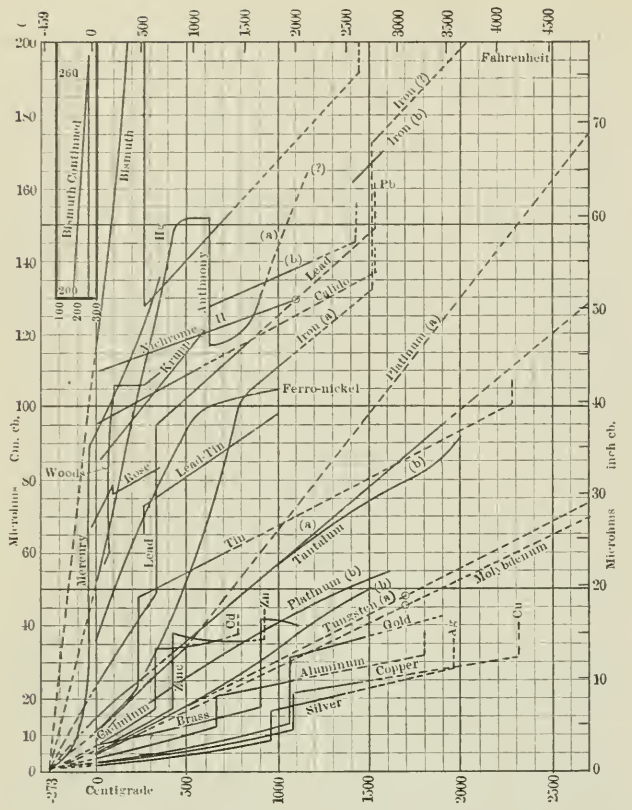


CHART 1

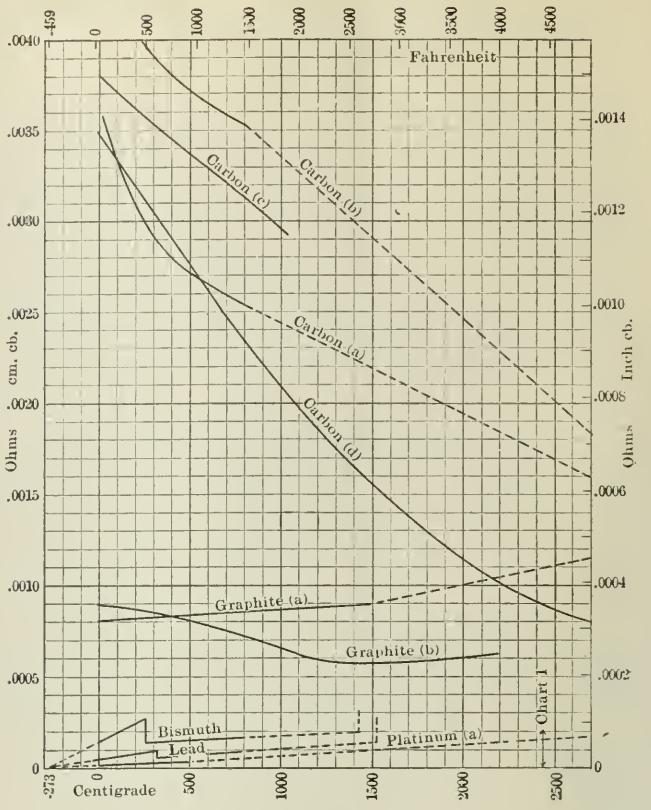


CHART 2

TABLE I
(Values in italics are merely exterpolated)

500°C 932°F.	Microhms Cm. Cb.
Silver, solid	5.0
Copper, solid	5.1
Gold, solid	6.62
Aluminum, solid	10.
Brass, 2-1, solid	12.5
Molybdenum, solid	*16.5*
Tungsten (a, b), solid	18.
Platinum (b), solid.	25.3
Cadmium, fused	34.12
Platinum (a), solid.	34.4
Tantalum, solid	36.
Zinc, fused	36.60
Iron (a), solid, about	52.
Tin, fused	54.62
Lead-tin alloy, fused	81.
Ferro, nickel, solid.	94.
Lead, fused	102.85
Calido, solid	109.
Krupp metal, solid.	115.
Nichrome II, solid.	119.
Bismuth, fused	139.9
Antimony, solid	152.
	Ohms
Graphite (b)	0.00080
Graphite (a)	0.00084
Carbon (a)	0.0027
Carbon (d)	0.0028
Carbon (c)	0.0033
Carbon (b)	0.0037
Carbon powder	0.22
Silicon	0.094 to 0.23
Lead chloride, fused, 520°	0.418
Silver chloride, fused	0.547
Lead chloride, solid	0.824
Silfrax B	0.92
Copper chloride, fused	2.50
Graphite grains	2.70
Carbon grains (b) about	4.8
Carbon grains (a) about	8.5
Kryptol	10
Refrax	19.7
Boron, about	60
Silicon powder	120.
Glass about	330
Iron oxide, Fe_2O_3, powder	1260.
Copper oxide, Cu_2O, powder	1570.
Manganese oxide, MnO_2, powder	2200
Copper oxide, CuO	5640

1000°C. 1832°F.	Microhms, Cm. Cb.
Copper, solid	9.42
Gold, solid	12.54
Silver, fused	17.01
Aluminum, fused	24.
Molybdenum, solid	*28.5*
Tungsten (a), solid.	*30.5*
Tungsten (b), solid.	33.4
Platinum (b), solid.	40.8
Brass, 2-1, fused	41.
Tantalum, solid	57.
Platinum (a), solid.	*66.*
Tin, fused	*68.*
Lead-tin alloy, fused	98.
Ferro, nickel, solid.	105.
Iron (a), solid, about	*111.*
Calido, solid	*122.*
Lead, fused	*125.*
Nichrome II	128.
Antimony (b), fused	136.
Bismuth, fused	*167.5*
	Ohms
Graphite (b)	0.00065
Graphite (a)	0.00086
Carbon (d)	0.0021
Carbon (a)	*0.0024*
Carbon (c)	0.0030
Carbon (b)	0.0034
Carbon powder	0.12
Silfrax B	0.84
Sodium chloride, fused	*0.90*
Glass, roughly about	*1.*
Graphite grains	1.7
Carbon grains (b)	1.9
Carbon grains (a)	*2.8*
Silicon powder	3.5
Refrax	3.7
Kryptol	4.8
Porcelain, about	15.
Manganese oxide powder	15.7
Copper oxide CuO, powder	18.
Zinc oxide powder.	26.7
Iron oxide, Fe_2O_3, powder	31.4
Quartz	110
Magnesium oxide, powder	1400
Alundum	8000

1500°C. 2732°F.	Microhms, Cm. Cb.
Silver, fused	*23.*
Copper, fused	*24.8*
Aluminum, fused	*29.*
Gold, fused	*37.*
Molybdenum, solid	*40.5*
Tungsten, solid	*43.*
Tungsten (b), solid.	50.
Platinum (b), solid.	52.6
Tantalum, solid (b)	74.
Tantalum, solid (a)	78.
Tin, fused	*80.5*
Platinum (a), solid.	*98.*
Iron (a), solid, about	*131.*
Calido, solid	*136.*
Lead, fused	*148.*
Iron (b), fused	166.
	Ohms
Graphite (b)	0.00058
Graphite (a)	0.00089
Carbon (d)	0.0016
Carbon (a)	*0.0022*
Carbon (b)	*0.0029*
Nernst filament, about	0.5
Refrax	*0.5*
Silfrax B	*0.7*
Carbon grains (b)	*0.85*
Graphite grains	*1.2*
Kryptol	3.4
Alundum, about	750.

tionate error in the thermometer scale, or something foreign to the real resistivity.

Owing to the fact that on account of their wide range, the values cannot all be plotted on the same chart, Table I is here added, giving the materials and their values in the order of their magnitude for the different temperatures, 500, 1000 and 1500° C., which might be termed, roughly, incipient red heat, bright red heat, and dazzling white heat respectively. In some cases the values are probably only crude approximations, hence should not be relied upon as anything more than showing the order of magnitude. Those given in italics are exterpolations and are, therefore, only probable.

Vapors are used as resistors in the ordinary arcs with carbon and other materials as electrodes, the vapors then being those of the electrode materials. Also in the mercury lamp, and in Moore tubes, Geissler tubes, etc. Figures were, however, not available, it being evidently incorrect to calculate the resistance from the voltage and current, because part of this voltage is or may be a counter electromotive force, and represents (when multiplied by the current) the energy of vaporization, including what is often called the latent heat of vaporization. Very grave errors might, therefore, be made by neglecting this important factor, and it is not always an easy matter to eliminate it. In some cases, like Geissler tubes, this factor is absent, but there may then be others like contact resistance, ionization, imparting velocities to ions, etc., all of which must involve some energy consumption which would be represented in the electric circuit by a counter-electromotive force. It might be argued that a condensation of vapor occurs at the other electrode and that there would then be an equal direct electromotive force counteracting the counter one. It is a question, however, whether such condensation actually produces an emf, and, moreover, it is known that some if not most of the condensation in the mercury lamps does not take place at the electrode, but by a pure condenser action which does not return the energy to the electric circuit. And in the carbon arc much of the vapor is burned, hence its energy is lost to the

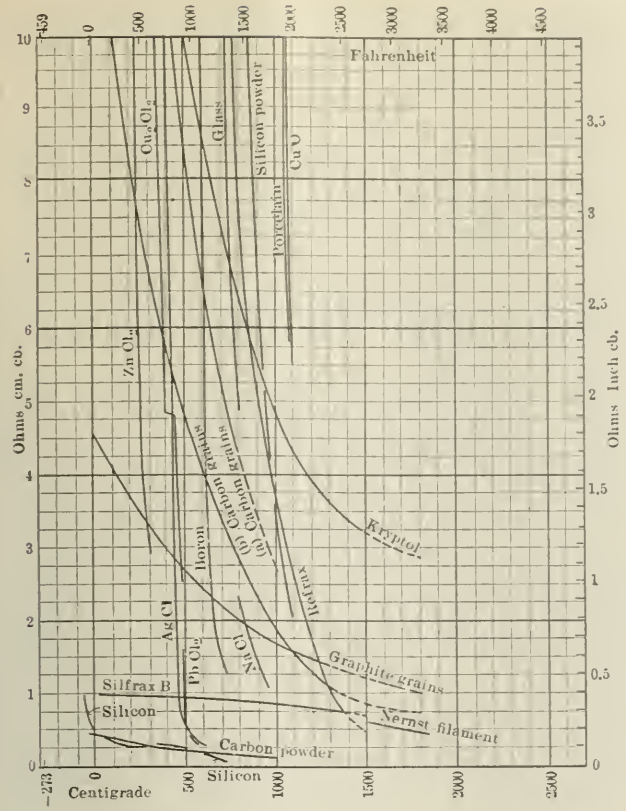


CHART 3

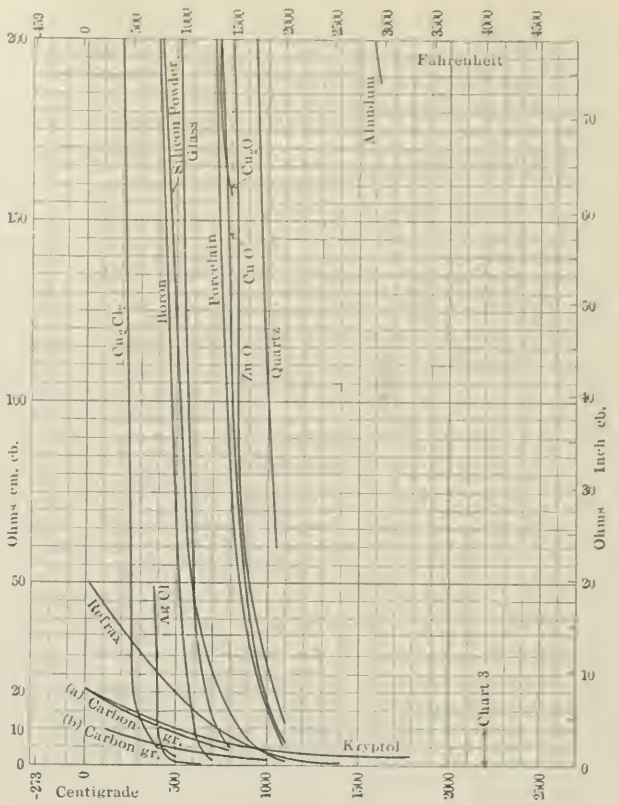


CHART 4

system. In a recent lecture Dr. Northrup announced that he expected to study this interesting question of the resistivity of vapors.

One of the curious features brought out by the present curves, if any dependence can be placed on exterpolations, is that bismuth at its boiling point may have a lower resistivity than the solid metal just before melting.

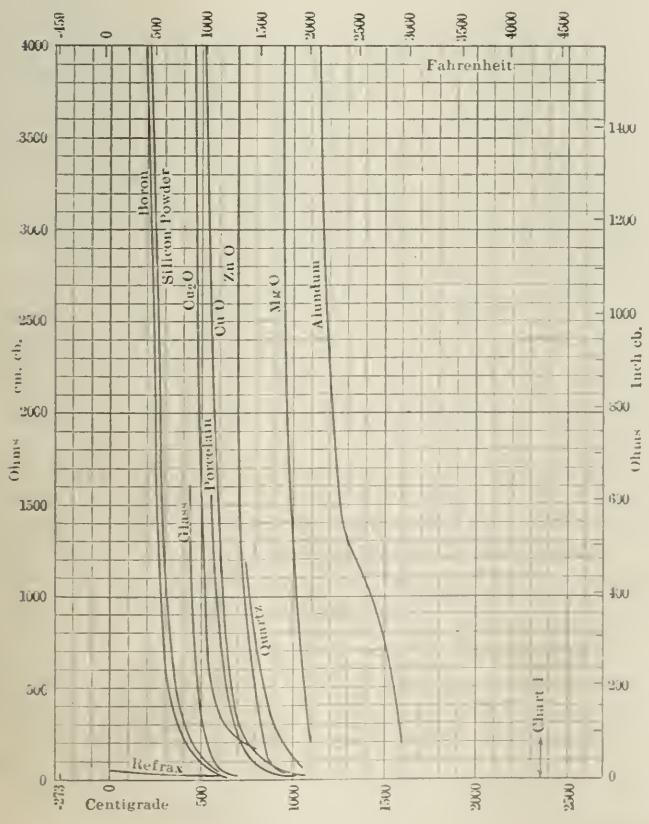


CHART 5

Northrup's recent determinations of the resistivities of molten metals, which are probably the best and most accurate, seem to have shown that these resistivities, for most metals at least, increase linearly; zinc and cadmium again are marked exceptions, behaving more like alloys than pure metal. If this linear increase is correct, interest naturally lies in seeing where these lines if prolonged downward would intersect the *X* axis, and especially whether they then meet at the same point. The present diagram enables this to be done, and it will be seen that most of them meet or nearly meet at what would be about —1600 deg. C. Tin, copper, and aluminium meet strikingly closely at this point, while gold does so quite closely, lead and silver fairly close, bismuth deviating most, though not greatly.

Northrup's values are for constant volume and are, therefore, what they purport to be, namely, the resistance of a cube of 1 cm at the specified temperature. Presumably, however, most liquid metals expand with temperature, as illustrated by mercury in a thermometer; hence if it were known at what rate they expand, it would be possible to deduce the resistivity of a constant *quantity*, weight, or mass, assuming it to expand linearly only, like mercury in a thermometer tube. Such a correction would make the lines steeper, as the resistivity would then increase more rapidly with the temperature, and these lines would then converge to a point nearer to absolute zero, but the expansion would have to be far greater than it seems to be, to bring the lines to this zero. It is of interest to note in this connection that in measuring and stating the temperature coefficient of the resistivity of solids, this factor of the change of volume with temperature is generally neglected, being too small; and when the test is made between two marks on a wire, the result is not really for constant volume but for constant quantity. A correction for constant volume might then possibly straighten out the lines of some of them which are now curved. Northrup, in a recent lecture (*Trans.*, Amer. Electrochem. Soc., Vol. 25, pages 387-8) makes an interesting comparison concerning the cubical expansion

of six liquid metals, tending to show that the ratios of their coefficients of resistance to their coefficients of cubical expansion, are nearly the same, namely, about 4.

In the discussion, Dr. J. W. Richards (page 390) makes some further suggestions concerning a possible relation between latent heat of fusion and the ratio of resistivities at the melting point.

NOTES ON THE CURVES

(Centigrade degrees and resistivities in microhm, centimeter cube units, unless otherwise stated. L. and B. means the Landolt & Boernstein tables.)

Silver. Pure. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, July, 1914, p. 85. Melts at 960.5 deg. C. or 1761 deg. Fahr.; boils at 1955 deg. C. or 3550 deg. Fahr. At 20 deg., 1.659 microhms, cm cube; 60 deg., 1.900; 960.5 solid 8.4, fused 16.6; 1000 deg., 17.01; 1100 deg., 18.19; 1200 deg., 19.36; 1300 deg., 20.54; 1340 deg., 21.01. Increase, solid, 0.60 microhm per 100 deg.; liquid, linear increase, 1.177 per 100 deg. Temperature coefficient, liquid, 0.00069. Exterpolated to boiling point 1955 deg. C. 28.

Copper. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, January, 1914, p. 1. Melts at 1083 deg. C. or 1981.5 deg. Fahr.; boils at 2310 deg. C. or 4188 deg. Fahr. At 20 deg., 1.7347; 1083 deg. solid 10.2, fused 21.3; 1100 deg., 21.43; 1450 deg., 24.22. Temperature coefficient when molten, from 1100 deg. to 1340 deg, 0.000381, based on 1100 deg. as the datum. Exterpolated to boiling point, 31.5.

Gold. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, March 1914, p. 287. Melts at 1063 deg. C. or 1945.5 deg. Fahr.; boiling point not known. At 20 deg., 2.316; 1063 deg. solid, 13.50; fused, 30.82; 1500 deg., 37.0. Increase per degree when molten, 0.014142.

Aluminium. Northrup. *Transactions Amer. Electrochem. Soc.*, April, 1914, p. 380 and 388. Melts at 658.7 deg. C. or 1217.7 deg. Fahr.; boils at 1800 deg. C. or 3272 deg. Fahr. Just before fusion, 12.5; just after, 20.13; 1120 deg., 25.

Brass. Cu., 63; Zn., 34.6; Pb., 2.4. Northrup. *Met. & Chem. Eng.*, March, 1914, p. 161. Presumably carefully made determinations. Melts about 900 deg. C. or 1652 deg. Fahr. Just before fusion, 17.5; just after, 41.62; 1100 deg., 40.

Molybdenum. Fink. *Trans. Amer. Electrochem. Soc.*, Vol. 17, p. 229. Melts at 2500 deg. C. or 4500 deg. Fahr. Annealed, at 0 deg., 4.8; hard, 5.6. Temperature coefficient per degree, 0.0050.

Tungsten (a). Fink. *Trans. Amer. Electrochem. Soc.*, Vol. 17, p. 229. Melts at 3000 deg. C. or 5430 deg. Fahr. Annealed at 0 deg., 5.0; hard drawn, 6.2. Temperature coefficient per degree 0 to 170 deg. C., 0.0050.

Tungsten (b). Pirani. *Tables Annuelles*, Vol. 1, p. 227. Old lamps. Gives ratios at various temperatures up to 1500 deg. C., to value at 20 deg. C. Latter here assumed to be 5.55 as given by him, p. 220.

Cadmium. Probably accurate determinations. Northrup. *Jour. Franklin Inst.*, February, 1913, p. 153. Melts at 320.9 deg. C. or 609.6 deg. Fahr. Boils at 778 deg. C. or 1432 deg. Fahr. At 0 deg., 7; at 321 deg., solid, about 17.1; liquid, 33.77; 700 deg., 35.78. Exterpolated to boiling point, 36.5.

Platinum (a). L. & B. Melts at 1755 deg. C. or 3191 deg. Fahr. At 0 deg., 11.0. Temperature coefficient, $a = 0.00394$, $b = 0.000000584$, between 0 deg. and 500 deg. C. The exterpolated values are probably only very crudely approximate.

Platinum (b). Pirani. *Tables Annuelles*, Vol. 1, p. 227. Gives ratios at various temperatures up to 1600 deg. C., to values at 20 deg. C. Latter here assumed to be 9.6 as given by him, p. 219.

Tantalum (a). Siemens. Melts at 2850 deg. C. or 5160 deg. Fahr. At 0 deg., 14.6. Temperature coefficient in per cent per degree 0 deg. to 100 deg., 0.33; 100 deg. to 1850 deg., 0.29.

Tantalum (b). Pirani. *Tables Annuelles*, Vol. 1, p. 227. Gives ratios at various temperatures up to 2000 deg. C., to values at 20 deg. C. Latter here assumed to be 14.6. At 2000 deg. it is 92.5.

Zinc. "Reagent zinc." Probably accurate determinations. Northrup. *Jour. Frank. Inst.*, Feb., 1913, p. 153. Melts at 419.4 deg. C. or 786.9 deg. F. Boils at 920 deg. C. or 1688 deg. Fahr. At 0 deg., 6; at 419 deg. solid, 17; liquid, 37.3; 850 deg. 35.74. Exterpolated to boiling point, 36.

Tin. Nearly pure. Probably very accurate determination. Northrup. *Jour. Frank. Inst.*, Feb., 1913, p. 153. Melts at 231.9 deg. C. or 449.4 deg. Fahr.; boils at 2270 deg. C. or 4118 deg. Fahr. At 0 deg., 11; 225 deg., 22; 235 deg., 47.60; 750 deg., 61.22. Liquid, linear increase, 2.61 per 100 deg. Exterpolated to 2000 deg., 93.8.

Iron (a). Melts at 1520 deg. C. or 2768 deg. Fahr., probably meaning pure iron; boils at 2450 deg. C. or 4442 deg. Fahr. This curve gives only crude approximations; pure iron being never used, accuracy is of no importance. The resistivity at zero was taken as 8.56 for pure iron as a mean of two values in L. & B. The rise with temperature based on that at zero was taken from the curve by Somerville, *Physical Review*, Vol. 31, p. 268, which values appear to have been determined with care, but they are unfortunately not given either as resistivities nor even in ohms, but merely relatively. The value when molten is a crude determination by the writer, of ordinary steel. The rise after melting is mere exterpolation, based on the general converging lines of other metals, no importance should be given to it. The bend in the curve at the point of recalescence is of interest.

Iron (b). Vom Baur. Molten iron and steel. No temperature given.

Ferro-nickel. 50 + 50. L. & B. at 0 deg., 36; 600 deg., 100; 1000 deg., 105.

Rose Metal. L. & B. Melts at 94.3 deg. C. At 0 deg., 64.5; at 93.5 deg., 78; at 250 deg., 80.4; at 350 deg., 83.3. The small fall at the melting point is exterpolated from the curves before and after; it may not be correct; it contains much bismuth which has a very great fall at its melting point.

Lead-Tin Alloy. 75.78 Pb, 24.22 Sn. Mueller. *Tables Annuelles*, Vol. 1, p. 222. Congeals at 263.8 deg. C. At this temperature 73.2; at 1000 deg. C., 98. Note that though an alloy the line seems straight.

Lead. "Test lead" free from silver. Probably very accurate determinations. Northrup. *Jour. Frank. Inst.*, February, 1913, p. 153. Melts at 327.4 deg. C. or 621.1 deg. Fahr. Boils at 1525 deg. C. or 2777 deg. Fahr. At 0 deg., 24; at 327 deg. solid, about 49.2, liquid 94.7; 800 deg., 116.20. Exterpolated to 1000 deg., 125, to 1500 deg., 148.

Calido. Elec. Alloy Company. Melts above 2800 deg. Fahr. or 1530 deg. C. Wire 0.010 in. diameter has 5.75 ohms per foot. Temp. coeff. 0.00019 deg. Fahr.

Krupp Metal, Nickel Steel. Thomas Prosser & Son. Maximum safe temperature 600 deg. C. or 1112 deg. Fahr.; at 20 deg,, 85.13. Temperature coefficient, presumably from 0 deg. to 600 deg. C., 0.0007007.

Woods Metal. L. & B. Melts at 69.8 deg. C. or 157.5 deg. Fahr. At 0 deg., 51.8; 50.3 deg., 57.8; 75 deg., 85; 350 deg., 109.5. Note that it rises considerably at the melting point, although it contains much bismuth.

Nichrome II. Driver-Harris Company. Maximum safe temperature 2000 deg. Fahr. or about 1100 deg. C. At 20 deg. C., 660 ohms per mil-foot. Temperature coefficient, 0.00009 per Fahr. deg.

Bismuth. Nearly pure. Probably very accurate determination. Northrup. *Jour. Frank. Inst.* February, 1913, p. 153. Melts at 271 deg. C. or 520 deg. Fahr.; boils at 1430 deg. C. or 2606 deg. Fahr. At 17.5 deg., 120; 271 deg. solid 267, liquid 127.5; 750 deg., 153.55. Exterpolated to boiling point 191.

Mercury. L. & B. Melts at —40 deg. C. or —40 deg. Fahr.; boils at 357 deg. C. or 675 deg. Fahr. At —183.5 deg., 6.97; at —40 deg., about 29; at 350 deg., 135.

Antimony (*a*). Nearly pure. Before fusion the values are only approximate. Northrup. *Jour. Frank. Inst.* February, 1913, p. 153. Melts at 630 deg. C. or 1166 deg. Fahr.; boils at 1440 deg. C. or 2624 deg. Fahr. At 650 deg, 117.07; 900 deg., 131.0. Exterpolated to 1000 deg., 158.

Antimony (*b*). Bornemann & von Rauschenplat. *Tables Annuelles,* Vol. 3, p. 258. Only after fusion. Exterpolated to boiling point, 145.

Graphite (*a*). Acheson Company. At 20 deg., 0.000320 ohm, inch cube. Resistivity according to Northrup, increases about 9 to 10 per cent from 20 deg. to 1500 deg., and more rapidly thereafter. Exterpolated part continued to the graphitization point here assumed roughly as about 0.0013 at 3300 deg., where this curve should meet those of carbon.

Graphite (*b*). Hansen. *Trans. Amer. Electrochem. Soc.,* Vol. 16, p. 329. Here based on his percentage values, p. 334, and what he seems to assume as the mean room temperature value, p. 339, namely, 0.00035 ohm, inch cube.

Carbon (*a* and *b*). National Carbon Company. Fine-grained electrodes (*a*) 20 deg. C., 0.0014 ohm, inch cube; 400 deg., 0.0011; 800 deg., 0.0010. Coarse-grained electrodes (*b*) 20 deg. C., 0.0020; 400 deg., 0.0015; 800 deg., 0.0014. At higher temperatures they say it changes by a linear function to the graphitization point, here assumed roughly as about 0.0013 at 3300 deg., hence the exterpolated curves have here been continued to this point where the curves should meet those of graphite.

Carbon (*c*). Somerville. *Physical Review,* Vol. 31, from the apparently well-determined temperature curve on p. 270, where, however, the values are only relative; 0.0038 ohm was here assumed as the basic value at zero, as he gives no actual resistances.

Carbon (*d*). Hansen. *Trans. Amer. Electrochem. Soc.,* Vol. 16, p. 329. He calls attention to the variability of the resistivity of cold carbon, depending upon what temperature it had been raised to while in use, the higher temperatures graphitizing it more or less. The present curve is the "parent curve" in his Fig. 3, based on the value 0.00137 ohm, inch cube, cold, which he seems to have used.

Carbon Grains (*a*). National Carbon Company. Sifted through 4 mesh and resting on 6 mesh, not tamped. At 20 deg. C., 8.2 ohms, inch cube; 800 deg., 1.7.

Graphite, Carbon (*b*) *and Kryptol Grains.* Jeffries. METALLURGICAL & CHEMICAL ENGINEERING, March, 1914, p. 154. Grains passing through 0.093-in. mesh and remaining on 0.0328-in. mesh. No pressure.

Silicon. Zimmerman. *Tr. Am. Electrochem. Soc.,* Vol. 15, p. 395. Very variable. Resistivity decreases rapidly with increase of temperature. Melts at about 1430 deg. C.

Carbon and Silicon Powders. Somerville. METALLURGICAL & CHEMICAL ENGINEERING, August, 1912, p. 484. Passed a 40-mesh screen. Column under about 3 lb. pressure. Results given as curves only. The carbon powder had about fifty times the resistivity of solid carbon, and the powdered silicon about 25,000 times that of solid silicon. Powders were placed and measured in porcelain tube. The present curve for porcelain (by the same author), however, shows that at the higher temperatures the resistivity of the tube was of approximately the same order of magnitude as that of the silicon powder, hence it would seem that the error introduced by the tube must have been quite great.

In the *Electrical World,* May 25, 1912, p. 1118, the same writer gives measurements on carbon and silicon powder the size of sand to fine dust, under various pressures. Carbon under no pressure, about 0.20 ohm; hence about fifty times that of solid carbon. Silicon under pressure of about 30 kg per sq. cm about 0.40 ohm; under no pressure it has about 500,000 times the resistivity of solid silicon. No curves are here given, as the data were all determined at room temperatures.

Silfrax B. Carborundum Company. Maximum safe temperature about 1800 deg. C. At 20 deg. C., 1.0 ohm, cm cube; 1400 deg., 0.7.

Refrax. Carborundum Company. Maximum safe temperature about 2100 deg. C. At 25 deg., 50 ohms, cm cube; 1400 deg., 0.65.

Nernst Filament. Wurtz. *Trans. Am. Inst. Elec. Eng.,* Vol. 18, p. 545. Length, 25 mm; diameter, 0.63 mm; 196 volts, 0.5 amp, hence 0.49 ohm, cm cb. No temperature given.

Zinc Chloride. $ZnCl_2$. L. & B. Melts at 262 deg. C. or 505 deg. Fahr. At 230 deg., infinity; just melted, 4.46 ohms; 310 deg., 290; results not very concordant.

Silver Chloride. AgCl. L. & B. Melts at 460 deg. C. or 860 deg. Fahr. At 380 deg., 47.6 ohms; 500 deg., 0.547 ohm; 650 deg., 0.214 ohm.

Copper Chloride. Cu_2Cl_2. L. & B. Melts at 434 deg., C. or 813 deg. Fahr. At 140 deg., 1000 ohms; 250 deg., 29 ohms; 400 deg., 4.83 ohms; 440 deg. (melted), 4.79 ohms; 490 deg., 2.52 ohms. Note that the resistivity appears to remain nearly the same for a while about the melting point.

Lead Chloride. $PbCl_2$. L. & B. Melts at about 500 deg. C., 932 deg. Fahr. At 500 deg., solid, 0.824 ohm; 520 deg., melted, 0.418; 580 deg., 0.372.

Sodium Chloride. NaCl. L. & B. Melts at 790 deg. C. or 1454 deg. Fahr. Freezing, 2.28; melted at 960 deg. C., 1.087.

Boron. Weintraub. *Trans. Amer. Electrochem. Soc.,* Vol. 16, 1909, u. 165. Only approximate. Melts at 2000 to 2500 deg. C. At 23 deg., about 1.7 megohms; at dull red heat, here taken as about 700 deg., a certain piece had a resistance of about 5 ohms, which would be roughly about 1.5 ohms, cm cube. The present curves are in a range where but few values were given by him, hence indicate but little more than the general order of magnitude.

Glass, Porcelain and Quartz. Somerville. *Physical Review,* Vol. 31, 1910, p. 261. Presumably good determinations. No figures are given for resistivities, only curves. Good data for temperature coefficients. Berlin porcelain begins to soften at about 1100 deg. C. It seems that all three of these materials were still solid over the ranges given. For quartz, the logarithm of these resistivities plotted against temperatures, gives a straight line. The values for glass plotted as conductivities do not give a straight line.

Various oxides in powder form. CuO, Cu_2O, MgO, ZnO, Fe_2O_3, and MnO_2. Somerville. METALLURGICAL AND CHEMICAL ENGINEERING, July, 1912, p. 422. The curves in the original article give the actual resistances and not the resistivities, although not so stated. They are here reduced to resistivities, and are only approximate, as accurate data for the reduction were not given. Pressure 2 to 4 lb. on a column 1 cm diameter. The powders were measured while in porcelain or quartz tubes, but as the present curves show that the latter materials have resistivities of about the same order of

magnitude at the same temperatures (according to the same author) an error of considerable magnitude must have been involved, hence they may not even be of this order of magnitude; the tests were therefore like measuring the resistivity of mercury in a copper or iron tube. The present compilation brings out just such features. The values for Fe_2O_3 and MnO_2 were so nearly like those for ZnO that the curves have been omitted. CuO melts at 1084 deg. C. or 1984 deg. Fahr. (almost exactly the melting point of copper); Cu_2O decomposes at 800 deg. C. or 1472 deg. Fahr.

Alundum. Grade RA 355. Al_2O_3. Fused bauxite. Northrup. METALLURGICAL AND CHEMICAL ENGINEERING. February, 1914, p. 125. Presumably a reliable determination. Melts at 2050 to 2100 deg. C. At 1600 deg., 190 ohms.

Philadelphia, Pa.

Has Titanium Any Influence on the Properties of Steel?

BY F. A. J. FITZGERALD

For several years the writer has frequently been asked the question: "Has titanium really any influence on the properties of steel?" The question has invariably been answered in the affirmative because of the evidence furnished by actual experiments and that gleaned from the voluminous and apparently trustworthy literature on the subject. For some reason, however, there undoubtedly exists a great deal of scepticism on the subject.

The reason for this scepticism is not very difficult to find for it obviously lies in certain characteristics of the manufacture of steel which are analogous to the older practice of medicine, a practice which indeed may exist in some quarters even to this day. There used to be, in the old days of medical practice, a wonderful form of treatment known as the "blunderbuss prescription," which consisted of as many constituents as the ingenuity of the doctor could combine with due consideration of the laws of compatibility. Usually there could be no question whatever as to the effect of the exhibition of the medicine as a whole, but for obvious reasons it was extremely difficult to separate the reactions of the various constituents. Now to the layman it certainly appears that the doctoring of steel is often governed by the methods of the blunderbuss school, and to this is added a large number of accidental occurrences which certainly influence the final product, and consequently make it extremely difficult to correlate various causes and effects.

No one watching a series of heats run off in a steel mill can fail to recognize the number of things happening during the manufacturing process which must affect the steel ingots. The temperature of the metal involves generally the personal equation of the melter, the rate at which the moulds are filled is apt to vary, there may be running stoppers, the way in which the steel is doctored by sundry additions varies. In the case of small heats you may sometimes see a melter make additions of substances which he conceals about his person and which may or may not influence the final result. Under such conditions it might be expected that the final product of the manufacture will show considerable variations when different heats are examined, and this is certainly found to be the case.

Probably no one will deny that it would be a great advantage if we could use perfectly pure and suitable materials for the manufacture of steel, melt these under uniform and perfectly controlled conditions and so eliminate the objectionable doctoring of the metal, whether by the blunderbuss or more scientific methods. This, however, is unfortunately impossible and, therefore, since doctoring must be done it should be as nearly scientific as possible. There cannot be any doubt at all that the great difference of opinion as to the effect of various additions used in the manufacture of steel is due to the ways in which the medication is exhibited and to the attention to or disregard of the laws of compatibility. Even when a single steel mill, where a more or less uniform practice is followed, is considered, it is impossible to avoid many variables, so that in order to arrive at conclusions about the effect of any one addition, such as titanium, it is necessary to make a sort of statistical investigation.

An article which recently appeared in the *Railway Age Gazette*[1] mentioned some tests which apparently would lend themselves to an inquiry of this sort, and the Titanium Alloy Manufacturing Co. allowed the writer to examine a number of records covering these tests. From these data were obtained which on analysis seem to show beyond a doubt that the addition of titanium to steel has an important influence on its properties. The data are derived from very complete reports on 155 heats, representing the production of over

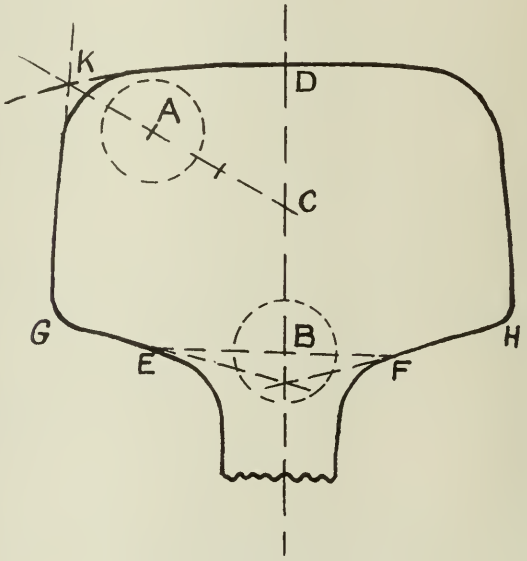


FIG. 1—SECTION OF RAIL

9000 tons of 100-pound steel rails, all made at the same mill and under as uniform conditions as could be expected. In 78 heats no addition of titanium was made, while in 77 heats ferro-titanium was added in the ladle. Here, then, there appears to be a sufficient number of observations on a large enough scale to eliminate to a great extent the effect of variable errors.

As everyone knows, the rail problem is a very serious one and an immense amount of study has been devoted to its solution. It seems to be believed by a great many authorities that segregation is one of the chief causes of trouble, and with this in view a method of detecting segregation has been proposed for use in the specifications for rails. Referring to Fig. 1, which represents a section of a rail, drillings are taken at places indicated by the circles A and B. The centres of B and A are found respectively as follows:

The points E and F are where the lines G E and H F leave the edge of the section. The line E F is drawn and bisected at B, which is the centre of the circle.

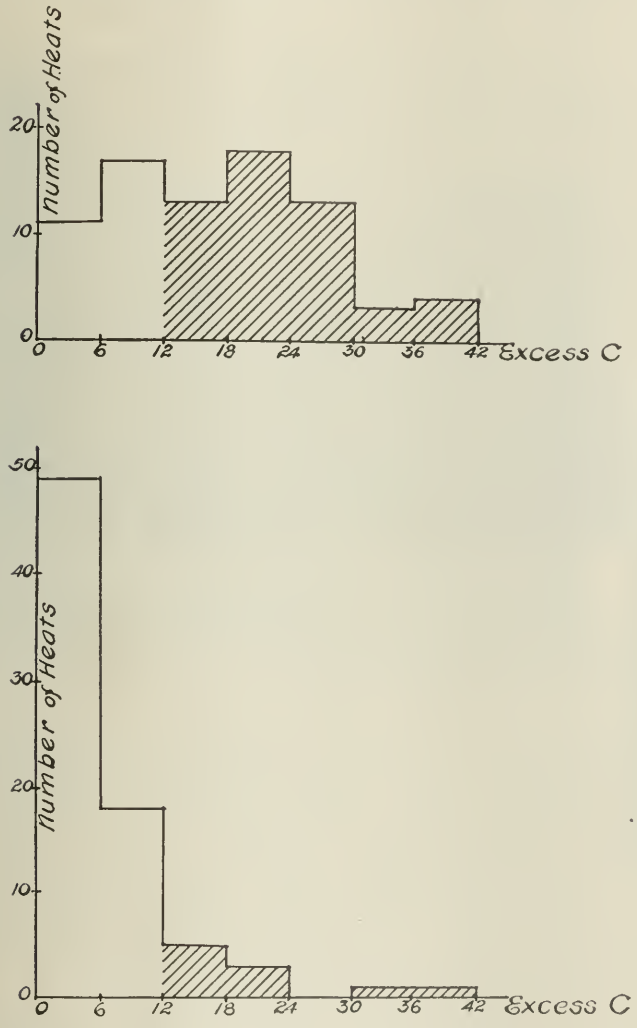
The line B D is drawn along the axis of symmetry of the section and bisected at C. The point K is the intersection of the prolongation of the curve D K with the line G K. Join C and K and then the centre A is found at two-thirds of the distance of C from the intersection of C K and the edge of the section.

[1]October 23, 1914.

The samples for analysis are made with a ⅝-in. drill and used for carbon determinations.

In the proposed specifications these samples are taken from A rails, i.e. the first rails made from the heads of the ingots after a 9 per cent crop. In general the carbon in the sample at B is found to be higher than that in sample A and it is suggested that whenever the carbon in B is more than 12 per cent greater than that in A the rail should be rejected. In the 155 heats under consideration this method of testing was used, since it was maintained that the use of titanium diminished segregation. Accordingly from every heat the Titanium Alloy Manufacturing Co. took the nineteenth ingot for applying the test and the Steel Co. took the eighteenth for a check test.

There are various ways in which the results obtained may be shown, but they are best illustrated by the diagrams of Fig. 2. In order to make the diagrams the various heats were divided up into seven groups as follows:



FIGS. 2 AND 3—DIAGRAMS OF RESULTS OBTAINED WITH HEATS OF STEEL WITHOUT AND WITH USE OF FERROTITANIUM

Group No.	Per cent excess of C. in web
1	6.0 or less
2	6.1 to 12.0
3	12.1 to 18.0
4	18.1 to 24.0
5	24.1 to 30.0
6	30.1 to 36.0
7	36.1 to 42.0

The number of heats falling in each group was then determined and from these the diagrams were drawn. The upper diagram shows the results obtained in the 78 heats where no titanium was used and the lower diagram the results from the 77 heats where titanium was used. In each case the shaded portion shows the heats where the carbon is in excess of the limit set by the proposed specification.

The test shows that where no titanium was used only 36 per cent of the heats gave A rails which came within the proposed specification limits, while with the use of titanium 87 per cent. would pass.

A more detailed examination of the 77 heats in which titanium was used clearly shows the influence the amount of titanium added has on the results. According to the advice of the Titanium Alloy Manufacturing Co. the amount of ferro-carbon-titanium used should be such that the quantity of metallic titanium added to the steel is 0.10 per cent. This, however, was not followed as in some heats only 0.075 per cent was added and in some as little as 0.053 per cent. The following table shows the effect of the amount of titanium added:

Titanium added. Per cent	Total Heats	Heats within specification limit. Number	Per cent
0	78	28	36
0.053	7	3	43
0.077	39	33	84
0.10	31	31	100

This seems to show that in order to get the best results at least 0.10 per cent of metallic titanium should be added.

While it may be argued that, as regards the amount of titanium which should be added, it is necessary that a larger number of experiments be made to determine the proper dose, there cannot be the least doubt that the question originally asked must be answered in the affirmative.

The FitzGerald Laboratories, Inc.,
Niagara Falls, N. Y.

Findings of the Selby Smelter-Smoke Commission

The Selby Smelter Commission appointed to settle the controversy between the Selby Smelting & Lead Company and the residents of Benicia, Cal., and contiguous agricultural territory, has filed its report with the Superior Court of Solano County, Cal. The commission comprised J. A. Holmes, director of the U. S. Bureau of Mines; E. C. Franklin, professor of organic chemistry, Leland Stanford, Jr., University, and Ralph A. Gould, chemical engineer, of San Francisco. The purpose of the commission was to determine whether the smelter was operating in violation of the court decree of July 16, 1908; the extent of violation, if any; and the manner of operation necessary to avoid violating the decree. A large corps of experts was employed to make various investigations. The commission has found that the smelter violated the decree with respect to damage to certain horses up to April, 1914, at which time a bag-house was installed and operated. No violation is found with respect to disagreeable odor, or as to damage to vegetation. It is stated further, that the decree will not be violated if less than 80 tons of SO_2 is discharged into the air in 24 hours. One of the interesting findings of the commission was to the effect that sulphurous gases from Dwight-Lloyd roasters could be concentrated by recirculation to the extent of 7.5 per cent SO_2, making it possible to produce sulphuric acid from the gas.

Missouri led all other states in the production of lead and zinc in 1913, according to figures compiled by the U. S. Geological Survey, although the production for the past year was less than that of 1912 due to a smaller output of zinc and decline in price for that metal. The total value of lead and zinc concentrates in 1913 was $21,109,358. Based on metallic content, the value was $29,494,064.

The Hardwood Distillation Industry in America*

BY EDWARD H. FRENCH AND JAMES R. WITHROW

In view of the economic importance of the utilization of wood waste, and the increasing interest being manifested in this utilization, it naturally surprises the inquirer that there is practically no literature upon this industry from the point of view of actual American practice. It may not be without value, therefore, to consider the progress made in hardwood distillation and to trace its development from its inception in this country. We have gathered together consequently and classified much of the information which we have acquired in the plants of this industry during an experience in its totalling about twenty-five years.

This tracing of the development of an industry of the magnitude of this one is peculiarly interesting to the engineer, since it shows the necessarily slow evolution of the industry in the hands of the unscientific manipulator, and serves to emphasize the advantages with which the modern chemical engineer is possessed, and serves also to indicate how much more rapid the development might have been in the hands of experienced chemical engineers. It indicates also that the future may, under the direction of the competent engineer, make advances of importance much more rapidly than in the past. This latter statement is significant when it is remembered that the advances made thus far have been due either to accidents or very often to workmen endeavoring to minimize the laboriousness of their work. As plants are operated on 12-hour shifts, this desire to economize energy may be readily understood.

For much of the historical information collected we desire to express our appreciation to Mr. Robert Mackay, who has been active in this industry for so many years. In fact, during the past fifteen years our own continued intimate acquaintance with Mr. Mackay has been not only of unusual pleasure but of continuous instruction. A history of this industry would be incomplete without mention of the fact, that due largely to his personality and integrity, the firm with which Mr. Mackay is identified, has had the unusual experience, in an extensive industry, of supplying engineering materials for every plant of this nature in the United States and Canada with perhaps two exceptions, for a period covering the past 25 years.

Early History

While charcoal burning was doubtless carried on in the earliest days in this country it was not until 1830 that James Ward began the manufacture of pyroligneous acid, at North Adams, Mass., according to Monroe and Chatard (12th Census, United States, Bull. No. 210, Chemicals and Allied Products, p. 34). No claim is made that the pyroligenous acid was carried further, though it may have been. We have ourselves no information on this matter other than the above citation. As far as we can ascertain it was not until 1852 that works in the modern sense were inaugurated for the distillation of wood for the production of volatile products, and their semi-refined products. This does not appear in agreement with W. L. Rowland (Special agent 10th U. S. Census on Chemical Products and Salt, p. 23) who is later cited by Monroe and Chatard (Ibid) and C. L. Campbell, METALLURGICAL AND CHEMICAL ENGINEERING, 1910, p. 155, all of whom state that the manufacture of acetate of lime and methyl alcohol was started in the United States about 1867 by James A. Emmons and A. S. Saxon in Crawford County, Pa. Our information in this case comes from various manufacturers who have been in this business from the earliest times or at least whose family connection with it goes back to the beginning. One of these sources is Mr. Neil Patterson, whose father was in charge of the original "Scotch Works," built in 1852. In this year The Turnbull Company of Glasgow, Scotland, who were engaged there in the copper and iron industry as well as that of wood distillation, built the first operation in this country, by way of expanding their old country business. The place chosen for this location was known as Milburn, New York, now Conklins Station, on the D., L. & W. R. R. not far from Binghamton.*

This Turnbull company brought with them their apparatus as well as men experienced with their methods. On account of these Scotch workmen the works became known as the "Scotch Works" and this name has clung to it to the present time, although the original workmen gradually went with new operations which started

FIG. 1—TYPICAL WOOD YARD IN PENNSYLVANIA

shortly after this one. They had much to do with the subsequent expansion of the industry, all of them being later in charge of new works.

It is interesting to note in connection with this first plant that it was a type that was copied in detail in the construction of those that followed, for many years afterward. All these plants were equipped with cast-iron cylinders 42 in. in diameter and 9 ft. long, set in pairs, thus each pair held about 1¼ cords of wood. The wood was cut 7 ft. long and the charge "run off" every 12 hours, and six days a week. The stills and pans were operated during these early days exclusively by direct firing. The fuel used for the retorts, stills and pans was the charcoal produced, over which was poured the residual tar to make a quick fire.

This original works was followed in 1865 by Emmons & Co., of Brookdale, N. Y. In 1868 Alonzo Smith started a plant at Sturroco, Pa.; Keery Brothers, Cadosia; Mandaville, Emmons, Corbett & Mitchell, Livingston Manor, N. Y.; King & Co., Acidalia, N. Y.; Hilton & Co., Hiltonville, N. Y.; Brand & Schlayer; Frink & Ross; Tyler & Hall; Inderlied & Co.; Bayless & Berkalue and Wright & Co. were also early in the field.

During the early part of this period of development the chief product desired was acetate of lime, for which from 12 to 15 cents per pound was obtained. The alcohol demand was almost negligible, that which was made was of very infeior quality and was kept in barrels, and most of it was lost by evaporation or through some "illegal vent." The charcoal also had but little commercial

*A paper read before the Philadelphia meeting of the American Institute of Chemical Engineers on December 4, 1914.

*Mr. J. L. Stuart, of Corbett & Stuart, one of the earliest firms in this business in this country, informs us that the date 1852, given by Mr. Patterson for the building of the Turnbull plant, should be 1849.

value and was largely consumed as fuel at the works, although a small local demand gradually developed starting with the neighborhood tinsmith.

The change from the old charcoal heaps or pits to the kilns probably came quite early and perhaps before any of the improvements we have mentioned. It was not until 1876, after the retort system was well established and markets for its products had been developed, however, that Dr. H. N. Pierce's inventions made it possible to utilize partially the products wasted in the smoke from the charcoal kilns in Michigan, where great quantities of charcoal were prepared for blast furnace use.

The earliest attempt at refining alcohol, so that it might be of commercial value, was made by a Mr. Pollock, a chemist living just out of New York City. In a short time a demand began to develop for this product, which steadily increased, and up until 1880 was at all times up to the dollar mark. It was during this period that the need of better refining was felt, as it was realized that a large loss was entailed in the refining operations. This necessity accounts for the coming of the Burcey pans in the early seventies. These are copper containers placed in the vapor line above the stills, with

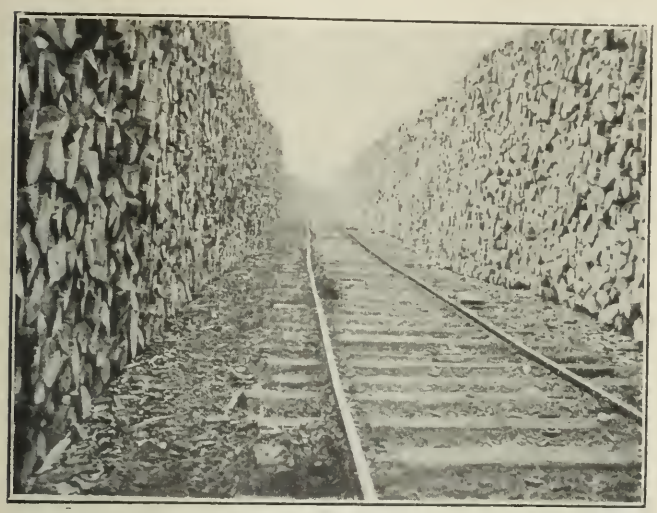


FIG. 2—CLOSE VIEW OF WOOD YARD

deflectors inside to project the vapor against the upper shell of the container, upon which a stream of water runs, causing fractional separation of the water from the alcohol vapor. The increase of alcohol product resulting from this improvement, together with the increasing market demand, made a central refinery necessary, and the producers united in building a refinery at Binghamton, N. Y., known as the Burcey Refining Company. This was in the middle seventies, and the plant is still in operation. It has served a good purpose, and to it was due perhaps more than to anything else the substitution of steam for direct fire distillation.

Before leaving this early history, it should be mentioned that the Turnbull plant, and, in fact, several succeeding plants, had but four pairs of retorts or 5 cords capacity to the charge, thus by obtaining two charges within twenty-four hours their total wood consumption was about 10 cords per day. To-day there are single plants operating 160 cords daily. Thus we have an illuminating comparison, at least so far as size is concerned, of the development of the industry.

Design of Apparatus

Even at the present time, there remain many plants using the old original retort system, with one very slight modification. Those first in service were of cast iron, while the later ones have shells of steel with riveted cast-iron necks and fronts. The purpose of this change was due to the fact that in the early operations, since the wood was then of much less value than later, and high yields were not so important, it was charred at a very high temperature, in order to increase as much as possible the capacity of the plant by shortening the time of firing. As cast iron was much more durable for these high temperatures than steel, this use of cast-iron retorts was universally practiced. When, however, with the coincident rise in the cost of wood, it was found that lower temperatures gave an increase of all products, it was seen that steel could be employed to advantage, for its lower weight permitted the turning of the retort. This turning refers to the saving in apparatus universally practiced and consists merely in the removal of the brick setting when the side in contact with the fire becomes buckled, rolling over the retort, and placing the uninjured part next the fire, thus materially increasing the life of the retort. This modern retort is of uniform size and design in all plants which still use this type of apparatus. The shell, as originally, is 42 in. in diameter and 9 ft. long, supported at the ends in a cast-iron cradle and having a cast-iron front, with door and lugs for pinning the door shut. At the rear is a neck 10 in. in diameter with attached condenser.

The evolution of the condenser is especially interesting, in view of the fact that when the original condenser was installed each succeeding plant accepted it as being of proper size, and the new installation was made the same size. Then from time to time some one would discover that an addition would yield more product and at once the arbitrary sized unit was changed.

FIG. 3—LOADED WOOD CARS AT OVEN

Originally the worm condenser was used, but it soon became apparent that the heavy carbon bodies caused clogging, and soon the log condenser was substituted and was used until the introduction of the upright tabular one. These log condensers were made by attaching, by a copper tee, a large-sized copper pipe, called the log, to each pair of retorts. Near the ends of this pipe were copper connections, joining the large log to a smaller one, and this in turn was similarly connected with others progressively decreasing in size. The whole log condenser lay in a plane at an angle of 45 deg. and the whole was surrounded by a wooden box with water inlet at bottom and outlet at the top. The joints were simply slip joints and were slipped together and "sweeled"; that is, wrapped with a cloth liberally covered with red lead, which after becoming dry or "set" offered a suitable and effective joint. At the ends of the logs were removable slip joint caps, for cleaning purposes, thus the cleaning from the heavy tarry and carbonaceous bodies was easily accomplished.

The first really important change in the general style of operation was that of replacing the old retort by the oven, which was done in the middle nineties, and is claimed to have been first tried out at Straight Creek, Pa. This change was wholly mechanical, and consisted merely of substituting for the retort a large rectangular oven, equipped with rails on the bottom for the purpose of carrying cars. These cars were loaded with wood and could be quickly pulled in and out mechanically and the charcoal unloaded outside the oven, greatly increasing the economy in this part of the operation over the slow hand drawing of the charcoal of the retort system.

There appears to be, however, much more advantage in this style of operation than the mechanical advantages which were at first anticipated, as an increased yield of products is obtained, due undoubtedly in part to more advantageous manipulation, but in our opinion also to the different chemical reactions that take place. In the old retort system complete carbonization of the wood took place in about sixteen hours, and it required in the oven system twenty-four hours, yet the temperature of the gases at the neck are higher in the latter, running at a maximum under skilful manipulation to about 330 to 360 deg. C., while in the former case the operation was consummated at not over 290 deg. maximum. This maximum temperature is obtained about midway or two-thirds of the run, at which time a very decided exothermic reaction takes place, and care must be exercised that the liquor is not "burned"; that is, that the temperature is not permitted to rise, so as to avoid undue formation of condensation products, which would be immediately seen in an increased flow of gas and a darkening of the crude liquor. This exothermic reaction, which also takes place in coal distillation, probably accounts for the increase in temperature of the uncondensed gases in the oven system, since no greater proportionate radiation takes place in this system than in that of the retort construction. At this particular stage, on account of the nature of the source of the heat (exothermic changes in the wood) a much more uniform temperature throughout the oven is maintained. This gives an excellent illustration of the possibility of considerable alteration even in the chemistry involved in a process when we change the mechanical manipulation.

An additional advantage obtained by this oven system is that the charge of residual charcoal may be drawn while the oven is still hot, thus economizing on the fuel necessary for reheating, while a partial cooling is necessary in the hand-drawn retort system.

The time lost during this cooling was saved in one design at Dahoga, Pa., where the retort at the conclusion of firing was removed by a crane from its vertical setting and replaced at once by a previously charged retort. It is stated in the meagre literature on this industry that "this type is probably most used."* This Dahoga installation, though it operated for many years, was the only plant that ever was installed in this country so far as we are aware, and certainly there is little likelyhood of any existing now, for this one was recently converted into an oven plant.

There is still a third system, which should be at least mentioned, namely, the kiln system. This was really the second in date of development, but the oven system was so closely allied in design and operation to the original retort system that the two were taken up together. The fact is, we would expect the logical development to have been: Charcoal heap—charcoal pit—charcoal kiln—by-product charcoal kiln—retorts—ovens, but this does not appear to have been the case, in this country at least. As in the coke industry we do not appear to have gone from bee-hive oven to by-product bee-hive oven, directly, but through the by-product oven, an outside and distinct invention, so in this industry charcoal kilns were only converted to the by-product kiln system after the development of the retort system.

When charcoal was produced in kilns, from 20 to 86 cords of wood were placed in a kiln constructed of bricks, and wood was used as fuel for carbonizing. The volatile products were lost through the opening provided at the top. With the advent of markets for alcohol and acetate some charcoal manufacturers placed a pipe connecting this opening with a suction fan and a condenser and thus collected the volatile products. The amount of product thus recovered is but a fraction of that recovered in a retort or oven system. In Pierce's system the flat-topped circular kilns usually hold 50 cords. They are heated by gas burned in a furnace under the kiln. For the sake of brevity, a description of these interesting kiln plants will be omitted since their recovery of by-products is low and they are confined almost exclusively to the blast furnace plants of Michigan, where they are steadily and rapidly being displaced by oven plants.

Yields

The low yield from the kiln system, which runs about 100 lb. of acetate of lime and 4 gal. of alcohol per cord, together with the low yields obtained by *rapid or quick* firing plainly show that there is a mean temperature

FIG. 4—A PENNSYLVANIA 66-CORD PLANT

which gives the maximum yield. Just what the curve of efficiency is, to our knowledge, has never been definitely determined in a commercial plant, though we have given it much experimental attention and others doubtless have worked on it also. In fact, there are so many factors to be considered in a comparison of experimental operations on a commercial scale that while the factors causing increased or lessened results are known, it is difficult to obtain accurate definite knowledge as to just how much each factor contributes to the results. For example, we know that Michigan plants under approximately the same construction and operation obtain less product per cord than those of New York and Pennsylvania without certain knowledge of the relative influence of the various contributing factors.

This lack of definite data on a commercial scale, so deplorable in most industries, results from the difficulty of obtaining successive tests with all conditions alike, for we well know that any variation, for instance, of temperature, has a peculiar relation to the results obtained. In addition it goes without saying that the variety or species of the wood enters largely into the

*Met. and Chem. Eng., 1910, p. 155.

results obtained, and even the part of the tree used may cause variation. For example, a charge made up wholly of heart-wood will give better yields under the same conditions than a charge of slabs, making due allowance for the bark. Again we have found that weight for weight, cord-wood obtained from the mature or virgin trees will yield higher than the small second growth; also we are convinced of a noticeable difference in results from wood of the same species grown on high and dry places, and that from low or marshy soil, the latter giving a slightly lower yield. Indeed it is interesting to hear the experienced operator maintain that wood cut in the winter months will give better results than if cut while the sap is running. We are, however, unable to verify this expression, and it is possible that some other factor may have been responsible for this often-repeated statement. It is also held by many operators that eliminating the consideration of extra fuel necessary for the charring of green or unseasoned wood, the results are not the same in finished product as from well-seasoned wood. We can see from these statements that with so many factors to be considered, it is extremely difficult to determine which enter most into the discrepancies between the various systems; retort, oven, and kiln. However, from the purely practical standpoint we do know that there is a marked difference between yields obtained from the different systems as well as from the two general localities extensively operating.

FIG. 5—START OF OVEN PULLING

If we compare the results obtained by the same system operated in the Allegheny Mountains with that of the Lake Superior region, we find that by taking the results on a yearly basis from a well-operated plant and calculating the wood on a basis of a cord 8 in. by 4 in. by 52 in., there should be obtained conservatively 216 lb. of 80 per cent acetate of lime, 11.3 gal. of 82 per cent crude wood alcohol, and 52 bu. of charcoal. The yield from the Lake district is slightly under this in alcohol, and decidedly so in the acetate yield, which is 175 lb. to 180 lb. on continued operation. However, here again we have at least two factors and it is difficult to determine their relative influence. First, in the Eastern field, beech predominates, while in the other hard maple is in larger proportion, and also slab wood is used much more largely. In fact, we have been unable to obtain data from a continued operation in which at least a small proportion of slabs was not used.

Construction

At this point it may be well to take up the question of construction, especially of the most successful and modern system, that of the oven, which is, with the exception of the mechanical manipulation, similar to the retort system.

The ovens are of uniform height and width, in most plants being 6 ft. 3 in. wide and 8 ft. 4 in. high, the length determining the capacity, running from 26 ft. to 54 ft. and holding from 5 to 10 cords. The steel used in the shell is usually $\frac{3}{8}$ in., while the bottom and back heads are of $\frac{1}{2}$-in. material. Ovens are built either with doors at both ends in order to withdraw the residual charcoal coincidentally with refilling the oven with wood-loaded cars, or in many cases, with a door at one end, the oven being loaded after the charcoal has been run into the coolers. In any event the door is hung upon a cast-iron frame riveted on the oven. This frame has a groove of about 1 in. for the use of asbestos packing and the cast-iron door is hung to the frame by riveted cast-iron hinges. The oven is stiffened by means of angle irons riveted perpendicularly on the sides, and on one side near the top are riveted 30-in. cast-iron nozzles, usually two in number, to which are attached the condensers.

The first ovens installed were placed upon piers in the setting, upon which were iron plates and rollers to accommodate expansion of the oven, but in the later settings the ovens are suspended from tee rails laid across the brick setting at the top and supporting the oven by means of U-bolts riveted thereto. The bottom of the oven is equipped with clips for holding the rails which carry the wood cars. These cars vary but slightly in length in different plants, running from 10 ft. 4 in. to 12 ft. 4 in. inside length and about 78 in. high, thus each car holds from 2 to $2\frac{1}{2}$ cords of 52-in. wood. Each has four 18-in. wheels with roller bearings running on 2-7/16-in. turned steel axles.

Immediately in front of the ovens are two charcoal coolers arranged in series and approximately of the size of the ovens. Into the first the hot charcoal is drawn from the retort, where it stands for twenty-four hours. From this cooler it is drawn into the second one for another twenty-four hours of additional cooling. These coolers are made of very light iron with cast door frames riveted on each end, and light sheet-iron doors. No bottoms are required as the coolers are simply placed on the ground and banked along the sides and doors with loose dirt.

To the nozzles heretofore mentioned are connected the condensers. These are upright tubular condensers, made with copper hoods having a removable head and are bolted to gun-metal heads which are bored for the copper tubes, usually $1\frac{1}{4}$-in O. D. seamless copper, and expanded into these gun-metal heads, the whole surrounded by a steel water-jacket with water inlet at the bottom and outlet at the top. Connected to a bottom pan bolted on the lower head is a goose-neck trap for trapping off the non-condensible gases, thus separating them from the pyroligneous liquor, which is run into a wooden tank. The gas from the charge is carried into a main gas line which runs to the boilers where the gas is injected under them by a small steam jet. This jet performs the additional and very important function of serving to reduce any back pressure on the ovens, thereby preventing leaks. In order to prevent this suction from becoming too pronounced and drawing over the lighter volatile products through the condenser into the gas line, a butterfly or clapper valve is arranged on the line and regulated by a spring so set

that any undue suction opens the valve, thus relieving the line.

Primary Distillation Operation

After this general outline of the first stage of the construction let us follow the operation to this point. After the loaded cars are run into the ovens the doors are pinned shut with taper pins driven into lugs which are a part of the casting of the door frame. The fires are started under the ovens and in about an hour the water distillation and first dissociation begins, the distillate being of a very light yellow color and having a tannin-like odor, and running about 2½ per cent of acid during the first hour when well-seasoned wood is used. Gradually this acid content rises until at about the fifteenth hour, when the content should be running from 12 to 14 per cent. After a few hours' running a small percentage of light tar begins to appear and steadily increases until at the latter end of the run tar is by far the larger constituent of the distillate. The acid content of the watery constituent gradually diminishes until it is almost negligible.

The product obtained under the usual practice, with average wood of at least a year's seasoning, is from 215 to 220 gal. of crude pyroligneous product giving an

FIG. 6—CHARCOAL COOLERS. A NEW YORK PLANT

acid titration of 8 to 8½ per cent and an alcohol content of 4 to 4½ per cent. The tar yield is from 22 to 25 gal. to the cord, with a residual charcoal in the cars of about 52 bu. of 20 lb. each. With green or unseasoned wood the total distillate is diluted and will run from 275 to 325 gal. of liquid.

In the early stages of the run the non-condensible gases are largely air and carbon dioxide. Therefore for the first few hours, and even after much of the hydrocarbons and carbon monoxide are accumulating in the gases they have no fuel value. However, the percentage of carbon dioxide diminishes rapidly, and from the middle to the end of the run the oven gas has an important fuel value. The total amount of gas will run from 11,000 to 12,000 ft. per cord.

As we have already intimated, the influence of the temperature of dissociation is extremely important, and the yields are much dependent upon its regulation. For example, if during the height of the run the temperature at the neck of the oven materially exceeds 750 deg. Fahr. much greater volumes of non-condensible gases are being formed, together with an excessive amount of tar, and it is quite possible to lose from 5 to even 10 per cent of charcoal, together with a serious loss both of alcohol and acid content. Rapid firing, however, without reaching excessive limits will materially increase the acid content at the expense of the alcohol, while slow, even firing, operating the oven at a period in excess of the usual twenty-four hours, will increase somewhat the alcohol production and lessen that of the acid.

The interesting results obtained from excessive firing arise, as we hope to show later, both from a difference in the chemical dissociation and also from the subsequent formation of condensation products.

In drawing the hot charcoal from the ovens, quantities of combustible gas remaining in the ovens would cause explosion on the opening of the doors. This is obviated by the introduction of live steam into the front of the oven for a short time before the drawing is made.

Handling the Crude Distillate

The crude distillate or pyroligneous acid, called in the works "raw liquor," is first pumped into a series of wooden settling tubs, connected with brass piping. The first tub, where the greatest amount of tar settles, is connected near its top with an overflow pipe to the secong tub. The second tub is connected with the third by a pipe somewhat lower, and this series of drops is continued so that the last tub is drawn from within about 18 in. from the bottom. The raw liquor thus settled free from tar is, as a rule, continuously run into the copper stills. These copper stills are for the purpose of distilling off the lighter volatile products away from the tars and oils which remained in solution in the settled liquor. They are from 7 to 10 ft. in diameter with proportionate height, made of 12 to 14-gage cold-rolled copper, and equipped with a steam coil, usually of 3-in. or 4-in. seamless drawn copper tubing and starting from about 18 in. from the top and running helically around the walls and on the bottom to midway between the center and pheriphery. For a 2000-gal. still from 300 sq. ft. to 400 sq. ft. of heating surface should be used. In addition each still should be supplied with a live-steam jet applied at the bottom and preferably through a copper ring having small steam openings.

After a copper still has run continuously for some time it gradually becomes filled with deposited tar and its flow of distillate diminishes. When this has reached a stage of very slow production, as it does every four days, the feed valve is closed and the live steam jet is opened, distilling the tar with live steam, thus obtaining considerable quantities of acid and light oils. This latter distillate is run into separate tubs, where the light oil on the top is withdrawn before the acid liquor is pumped into the original copper still distillate which has been run into a wooden "mixing tub." The tar from the settling tubs is usually distilled in a separate tar still, sometimes made of wood, and distilled as has been that just described. This practice is followed as it permits the separation of the oils independently and without allowing them to come in contact with the original distillate, in which a portion would dissolve, thus the bulk of the distillate contains less impurities by this practice.

The mixing tub is usually from 12 to 14 ft. in diameter, and 4 ft. high, having a very heavy wooden stirring arm fastened to the end of a heavy shaft, operated by a slow moving gear at the top. Slacked lime is slowly added to the liquor in the tub, which contains its own indicator, the liquid changing at the neutral point to a pronounced wine color. For maximum yields, however, the addition of lime, probably owing to the acetic esters present, should be continued until this color has been followed by a yellowish one and until a bead appears or bubbles form on the surface and which disappear slowly. A very small further addition

of lime at this point causes the acetate to stick to the pans when evaporated and prevents satisfactory crystallization. Under-neutralization also causes inferior quality in crystallization, and before final drying the acetate has a decidedly black color instead of a rich yellow brown, and there is an accompanying loss in product owing to the esters lost.

From the mixing tub the neutralized liquor is jetted or run into an iron still known in practice as the "lime lee" still. In a few plants this is equipped with either Burcey pans, or in some more modern works with a fractionating column, although most plants do not fractionate at this point. The customary practice is simply ordinary distillation. The crude alcohol starts over at about 20 per cent on a Tralle scale, but quickly rises to 35 per cent and at times 40 per cent, gradually dropping in percentage to from 15 to 20, at which strength it continues for some time and then drops rapidly to 5 per cent or 6 per cent, at which point it seems to hold stationary again for a long period. After all of the alcohol has been distilled over, a valve in the vapor neck is closed and the residual acetate solution is blown, by means of live steam pressure applied in the still, to an iron settling pan above the top of the

FIG. 7—DUMPING CHARCOAL

ovens, where the excess lime and insoluble impurities settle out in a few hours. The acetate liquor is then drawn into flat steam pans having a jacketed bottom for steam supply, the pans usually being about 16 ft. long by 8 ft. wide and 18 in. deep. Here the acetate liquor is boiled rapidly until crystals appear on the surface near the edges, when the steam is reduced so that the crystalline film which forms at once on the top does not break, which would cause it to fall to the bottom and form a hard crust. Care must be exercised in this "seeding" process, as it is called, or a great quantity of this exceedingly hard crust or scale will be produced, which is unfit for the market. After this "seeding down" has continued until the whole mass in the pan has reached a very thick mushy consistency, it is shoveled out on the acetate or "kiln floor," which is a smooth brick or tile covered floor over the top of the ovens. Here the acetate is continually turned until dried and ready for sacking and shipment.

The "weak alcohol" from the "lime lee" still, containing from 9 to 12 per cent of acetone and alcohol, is accumulated and distilled in an iron still having either 5 or 6 Burcey pans or a column. This distillate is the final crude product produced by the works, and is usually shipped to a central refinery, although a few plants refine their own product. In this distillation all the product coming over above 60 per cent is run into the storage tank, and the lower fraction is put back with the lime lee distillate for further distillation. The finished crude is sold on a basis of 82 per cent and contains about 16 per cent acetone.

Returning to the copper still residue, the tar from these stills, as well as that from the tar still, is run into a sump and from there jetted under the boilers for fuel. The two fuel products, gas and tar, furnish approximately 35 per cent or 40 per cent of the necessary fuel for all operations.

Before leaving this subject of operation it might be said that many of the earlier plants omitted this copper still distillation, neutralizing the raw liquor directly after settling and thereby obtaining the "brown acetate" of commerce, which is to-day practically without market. This brown acetate runs from 60 per cent to 65 per cent acetate.

Production Costs

The costs of producing the products above mentioned have been on a constantly increasing scale, owing in a large measure to the increasing cost of cord-wood and stumpage. During the past fifteen years in the eastern district, stumpage in suitable location has been sold for as low as 15 cents per cord, while to-day 75 cents to $1 is the approximate average. The cost of cutting varies from $1.15 to $1.35 per cord in fair timber, and in scattered timber $1.50 is sometimes paid. To-day, including transportation, piling, etc., this will make the cost on board oven cars $4 to $5 per cord, though wood is being put in for as low as $3.50 by users of mill-waste or by those having long standing holdings.

This gradual rise in the cost of wood is due to natural causes, among which are the increase in stumpage cost due to the ever-decreasing supply, and the natural rise in labor, together with increased length and cost of transportation. With the exception of one possibility, there appears to be no hope of any future lowering of costs. This one exception, a new cord-wood splitting machine, appears from our examination to have merit, and presents an entirely new system of cord-wood production. It is generally conceded that cutting and hauling the large log is less expensive than cutting and handling the cord-wood at the stump. The tree is therefore cut in logs and large limbs and transported to the machine, where a slide carries it first to a cross-cut saw, which cuts it into the proper lengths. The sawed pieces continue to a platform where they are either split in halves or quartered by one blow. The split wood automatically moves by a slide to the railroad car or wagon. It is claimed that under suitable conditions 50 cents per cord, or in some instances even more, may be thus saved. We have been unable to see continued operations of this machine as yet, and consequently cannot verify this saving cost, but are inclined to believe that at least some reduction in wood cost is possible by this means.

The cost of fuel for a crude works, in addition to the tar and gas used, of course varies with the available supply. In the New York and Pennsylvania districts,

TABLE I—PRODUCTION COSTS PER CORD OF WOOD

Wood (maximum) per cord	$5.00
Fuel	1.15
Labor	1.25
Lime, 0.96 bu. at 19 cents	.18
Bags (acetate)	.14
Freight (acetate, 16 cents per 100)	.35
Freight (alcohol)	.10
Selling commission acetate	.11
Insurance, per cord	.068
Taxes, per cord	.112
General expense	.57
Total	$8.85

when coal is used, this cost will amount on an average to $1.15 per cord, and when natural gas at 15 cents per thousand feet is used the cost is but slightly more. The labor at the plant is usually counted at $1.25 per cord.

The summation of production costs given in Table I (p. 35) will be generally accepted as a fair basis in considering investment in new installations.

Production Values

With the present slump in markets the values herein set down are low, especially that for acetate of lime. The past 10-year-average would be about $2 per hundred, while at present the market is slow at $1.75 per hundred.

Alcohol (82 per cent), 11. gal. at 25 cents	$2.75
Acetate of lime, 216 lb. at $1.75	3.78
Charcoal, 52 bu. net at 6¼ cents	3.38
Total crude value	$9.91

This gives a production cost of $8.85 and a sales value of $9.91 per cord. It will be noted that no selling costs except in the case of acetate of lime have been included, because in the works not refining or making the finished products, which are in number far in excess of those who do refine, the alcohol is sold under contract to the refiner, and the charcoal is either, as in the case of those plants in the Lake district, consumer at iron furnaces in connection with the plants, or as in the eastern field handled by a general sales agency controlled by the manufacturers, proportionately to their daily production capacity, yielding to the producer about the above mentioned figure at present.

These production costs are based on the yields in the eastern field, which, as pointed out, were higher than those of the Lake region. This discrepancy is compensated however by the fuel wood costs being lower in the Lake region, owing to the fact that in most instances mill-waste is used. The general relation between the two fields of operation in this production cost and product value is therefore approximately the same. It is undoubtedly true that many manufacturers can show much greater net profit than the above figures indicate, because of cheaper wood and fuel, and in some instances because of plant design.

Costs of Installation

Eliminating the cost of wood supply, $2,000 per cord per day production is counted as a reasonable installation cost for a plant as described, for producing crude products. For instance, the cost of boilers, ovens, cars, coolers, pumps, etc., is substantially $650. Copper work, including stills, condensers, piping, etc., approximates $450. Brick work for ovens and boiler setting, etc., will come to about $190. These three general items are more or less about a fixed estimate, varying, of course, somewhat upon the price of materials at the time. The location, buildings and general costs vary with the design and the desire of the builder. However, the above stated general figure of $2,000 is a fairly accurate estimate, unless elaborate construction is undertaken.

Large Scale Experimentation

Realizing the possibilities and necessity of counterbalancing the increasing cost of production, several large operators have made extensive large scale experiments with a view of increasing yields and saving production costs. Unfortunately the results obtained thus far have not justified the expenditures made in spite of many optimistic claims (Met. and Chem. Eng., 1913, p. 434), owing in a measure to the many unlooked for complications which arise between the laboratory and the works scale. Of the great amount of work which has been done along this line with which we happen to be familiar, space permits the citation of but a few illustrative instances.

In the fall of 1908 certain men largely interested in the business went to Germany to investigate developments there and returned with a process for eliminating the copper stills and making gray acetate of lime directly from raw liquor, a proposal which had already been made and studied in this country. This process had been reputed to be in successful operation in Germany. It was in fact merely the application of the cup column to the neck of the ovens. The cups and openings were of course of larger size than in the customary column, but in effect this really was all that could be claimed for the new appliance. It was held that the pyroligneous vapors, passing through the condensed

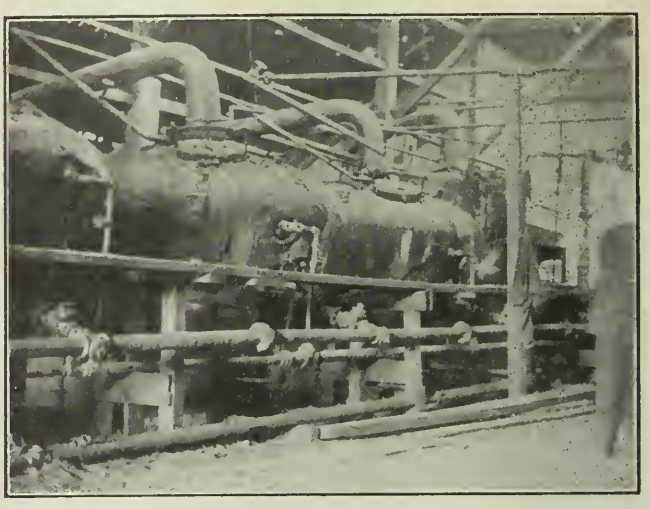


FIG. 8—ANCIENT TYPE OF COPPER STILLS, FORMERLY DIRECT FIRED, THEN CONVERTED TO STEAM HEATED BY A NOW DISMANTLED RETORT PLANT

tarry liquor, were freed from their impurities by this means and that gray acetate could be produced from the resulting raw liquor by direct neutralization. Educated or impressed by the then incomplete American investigations mentioned, these men permitted themselves to be carried away by the assurances of the German engineers and, as has happened several times in our industrial chemical development in more or less identical circumstances, without adequate experimental investigation they equipped a large plant with this apparatus at an enormous expense, the copper work for which alone exceeded $80,000. The plant did not prove satisfactory.

It will at once be seen from foregoing statements in this article, that there were two fundamental reasons which explain, in our opinion, the failure to obtain the desired results. First, as pointed out, mechanical clogging of the apparatus would occur, as was the case in the original worm condenser; and second, as we believe, the valuable products readily form condensation products with the unsaturated hydrocarbons and aldehydes present in the distillate. Certainly the passing of these vapors through the hot tarry liquid would tend to increase this chemical reaction. Moreover, the apparatus caused back pressure on the ovens and required a suction to overcome this objection. This increase of suction would tend to bring the vapors through the cups and the condensers at a more rapid rate, which of course would lessen their efficiency.

Later another process, also brought from Germany, was tried, which was in effect the same as the one

above described, except that the vapors were forced through a body of hot tar for the purpose of washing them, but this also was not successful. In our opinion this was for the same fundamental chemical reason as mentioned above.

A process for accomplishing this result, but not as yet entirely developed, from which some very satisfactory results have been obtained, is based upon a totally different theory from those mentioned. This method places a fractional condenser on the neck of the oven, which is maintained at a temperature sufficient to liquify the high boiling tars and oils. These, however, are largely mechanically carried along by the uncondensed and non-condensible gases, while a part of the tar is run off through a goose neck on the bottom of the fractional condenser, the uncondensed vapors and the non-condensible gases with their suspended tar and oil liquids are carried into the bottom of a centrifugal basket or drum, installed in a copper container and having small perforations inside of the drum, which is supplied with wings to give a rapid motion to the gases. This centrifugal action throws the liquid particles or mist against the side of the container, on which are deflectors set at an angle opposite to the

FIG. 9—SODA STILLS. WOOD ALCOHOL REFINERY

direction of the moving drum. Thus the condensed bodies are forced to the bottom of the container and out of the zone of circulation, through a goose neck into the tar receiver, while the vapors continue to a second condenser and are there condensed, the wood gas being trapped off in the usual manner.

This process has given uniformly increased yields of product, but exact data as to saving, yields and cost of operation have not been determined as yet. A little over one horsepower is necessary for the operation of a 7-cord machine until speed is attained, then three-fourths hp. is necessary.

The increase in product yield with this method is probably due to the fact that the vapor contact with the condensed and unsaturated bodies present is reduced to a minimum.

Another attempt at fuel conservation, which it seems should be possible of accomplishment, relates to the evaporation of the acetate liquor. As has been seen, much heat is necessary for evaporation of this liquor, and this method attempts to utilize the high temperatures of the gases at the oven's neck before they enter the condensers. We are not aware of any installation of this nature, although patents have been issued for accomplishing this end. Nevertheless, as it involves what appears to be a wholly mechanical manipulation there should be no great difficulty in saving at least a portion of this waste heat. Here again it can be seen that experimentation to accomplish this end is costly, since all experimental changes necessitate considerable financial outlay if tried on a large oven, and also involve interruption of regular operation which must from time to time inevitably occur.

Under this head of experimentation may properly come an elaborate attempt to utilize hardwood sawdust for alcohol manufacture. This was undertaken in 1903 by a well known lumber company in Cincinnati, who endeavored to destructively distill sawdust continuously by means of an endless belt which carried the sawdust through an oven for the purpose of carbonizing, tapping off the pyroligneous vapors and obtaining an uninterrupted production of charcoal, which was briquetted. The distillate was handled in the usual manner.

It can be readily seen that sawdust can not be destructively distilled in bulk, as is cordwood, for the insulating space between the particles prevents the heat from going through the mass. This explains the reason for the endless belt.

No expense was spared either in buildings or equipment, the buildings being of stone and the equipment of the best; the whole costing probably $200,000. Notwithstanding this outlay the operation was a complete failure, the plant being dismantled within a year and the buildings used for other manufacture. The high fuel cost in attempting to overcome the resistance to radiation in such a mass was an important item in the high production cost which resulted in the failure. In addition, sawdust charcoal is a more dangerous fire risk than common charcoal, in the handling of which in the ordinary plant special arrangements are necessary.

Within the past five years some plants have installed double and triple effect evaporators with a view of fuel economy and reports as to the results are very contradictory, but the continued use indicates at least partial success. One Michigan plant is successfully drying its acetate with a drum and belt dryer. Vacuum drying for acetate has been tried, but we are unaware of any success, as the resultant product is a powder which the market demands the crystal.

Refining

From the time of the formation of the already mentioned Burcey Refining Company, the usual plan of manufacture contemplated only the production of the crude product as described, selling the product, those of the Eastern field, largely to a Buffalo refinery, and the Michigan manufacturers to Detroit, and up until the passage of the Denatured Alcohol bill by Congress they received a price usually ranging from 40 to 75 cents a gallon for the crude alcohol. After the passage of this act, and with the purchase of the Detroit plant by the one at Buffalo, the price of crude was at times as low as 15 cents per gallon, and during this period of adjustment intense depression prevailed amongst the crude producers, as it was feared that ethyl alcohol would largely supplant methyl. It was found, however, that the trade, particularly the paint trade, preferred wood alcohol even at a slightly higher price, and this fact virtually saved the industry. With the formation of a refining company among eastern crude operators representing somewhat over 1000 cords daily production, and the erection of a refinery at Olean, N. Y., the monopolistic control of refining was immediately reduced. A very acceptable dead rental was paid to the crude producers for their uncompleted refinery, as well as a substantial increase for their crude product, which eventually reached and is maintained at about 25 cents per gallon of 82 per cent product.

The method first employed by refiners was merely that of fractional distillation, and we all perhaps will remember the yellow, ill-smelling wood alcohol of commerce. Later, and for a long time, bleaching powder and sulphuric acid were used before the final distilla-

tion. This materially improved the product, but with the improvement of the columns used, treatment with sodium hydroxide and distillation is all that is necessary. The NaOH serves the purpose of polymerizing the aldehyde impurities. It also saponifies both the tarry matter and esters. The formerly objectionable acetone present, which distills with the heads, now has its own market value under the name of acetone-alcohol and is used in varnish removers, as a solvent in the rubber and other industries and also as a carrier for acetylene gas in lighting systems. Thus this 16 to 18 per cent of impurity is now in fact an added value to the refiner.

Markets

Prior to the present unfortunate European situation the average production of acetate of lime from the manufacturers in this country amounted approximately to 7000 tons monthly, and we are informed that the total European and Canadian production is almost equal to this, of which tonnage Austria-Hungary furnished about two thirds. The plants in Europe, however, are usually on a very small scale in comparison with those in this country. Sweden alone has plants of a size in

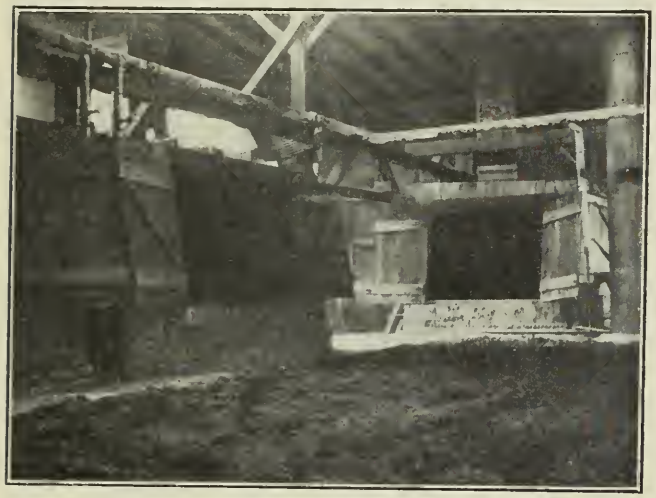


FIG. 10—ACETATE PANS AND KILN FLOOR

anyway comparable with the larger ones here. Of the production of acetate in this country, from 50 to 60 per cent is exported, a considerable percentage to or through Belgium. Of course, it will be understood that these statements refer to the market situation before it became demoralized by the European war, although for a year prior to the declaration of war there had been a pronounced stagnation of the markets both at home and abroad.

Of the acetate of lime consumed in this country, by far the largest percentage goes into acetic acid production. The hardwood industry is therefore vitally connected with this acetic acid industry, and one of the most important developments in the last decade is the successful beginning made in combining the crude manufacture and this refined or finished product manufactured in the same plant. Such combination plants have shown crude acetic acid yields in continuous operations running 92 to 96 per cent of theory, using 5 per cent sulphuric acid in excess of that theoretically required, and giving on a continued daily production of 4000 pounds, with a yield of 91 per cent of the possible theoretical yield, refined acetic acid of the finest double distilled quality.

The chief individual acetic acid market demands in this country are from the manufacture of white lead, paint colors, the textile and leather industries, although in the aggregate the small consumers such as the laundries, ink and drug trades, consume great quantities. This country prohibits the manufacture of acetic acid vinegar, but its production is permitted abroad.

The consumption of export acetone produced in this country is chiefly by England, and Italy is just now a large consumer. The industry is in a particularly thriving condition at the present time owing to its use in production of explosives for the European war. There should be obtained 20 to 22 pounds of acetone per 100 pounds of acetate used, and in connection with the crude works acetone production is very profitable, as the general operating expenses are low. Of course its use in this country was very large for explosive manufacture and for the production of chloroform under the well known Rump patents, regarding which there was so much patent litigation some years ago and which as you know were upheld. In comparatively late years, however, a large Michigan concern has produced chloroform commercially from carbon tetrachlorid, which has probably influenced somewhat the acetate consumption for this manufacture. There are four plants in the United States producing acetone for the market and within the past week ground has been broken in Pennsylvania for a fifth plant. There is but one plant operating in Canada, to our knowledge.

Ten years ago the steel industry consumed by far the major percentage of charcoal produced. This percentage however has decreased considerably owing to the improved methods for steel production. Many industries such as cutlery and car wheel manufacture demanded charcoal iron, but in these and many other instances coke iron has been substituted. This falling off in the proportionate use of charcoal in iron production has been made up in an increased domestic demand. Charcoal is now sold in small paper sacks in many cities for use both in hotels and private families.

The production of crude wood alcohol amounts to between 10 and 11 million gallons per year, and of course it has innumerable uses, including that of the paint industry, which is the largest single user.

Space will not permit in a general article such as this, of going into details regarding production and markets of the other products such as formaldehyde, creosote, etc., which are directly or indirectly derived from hard wood distillation.

Distribution of Plants

Although not in agreement with any published figures, we place the distribution of distillation plants as follows:

Michigan	8	oven plants carbonizing	1032	cords daily
	5	kiln plants carbonizing	1050	cords daily or
	13	plants carbonizing	2082	cords daily
Pennsylvania	33	oven plants carbonizing	1424	cords daily
	13	retort plants carbonizing	215	cords daily or
	46	plants carbonizing	1639	cords daily
New York	7	oven plants carbonizing	256	cords daily
	17	retort plants carbonizing	362	cords daily or
	24	plants carbonizing	618	cords daily
Wisconsin	2	oven plants carbonizing	96	cords daily
	1	oven-kiln plant carbonizing	250	cords daily or
	3	plants carbonizing	346	cords daily
Kentucky	1	oven plant carbonizing	20	cords daily
West Virginia	1	oven plant carbonizing	49	cords daily
Tennessee*	1	oven plant carbonizing	32	cords daily
Vermont	1	retort plant carbonizing	16	cords daily

This makes a daily capacity in this country of 2909 cords in 53 oven plants; 593 cords in 31 retort plants and 1300 cords in 6 kiln plants or a total of 4802 cords in 90 plants.

In Canada there are 9 oven plants charring 424 cords daily and one retort plant charring 48 cords, or a total of 472 cords in 10 plants. This makes a total for America of 5274 cords per day in 100 plants.

*A recently constructed 16-cord retort plant now being converted into an oven plant.

These figures will mean more to us if we remember that 5000 cords of wood represent a pile 4 ft. high and 52 in. wide and 7.5 miles long, weighing when seasoned approximately 10,000 tons.

These figures show the importance and size of the industry in this country.

Conclusion

It will be evident that the chief economic drawback in the present manufacture is the fact that most of the plants do not manufacture the finished products, thus in general it may be inferred that two sets of freight charges, commissions and handling expenses are required before the products reach the consumer. For instance, with acetate of lime at $2 the net return to the producer is about $1.75 per hundred.

A large part of this difference could easily be saved by undertaking the manufacture of the finished product at the crude plants.

Hitherto such combinations of crude and finished product manufacture have been thwarted in the majority of cases by an almost complete monopoly of the finished products by certain groups of chemical manufacturers, who by various manipulations maintained control of markets, or who were able to dominate the situation, as in the case of acetic acid, by their regional control of sulphuric acid manufacture, or even attempted control of pyrites importation. The violent market fights which have developed because of these facts have

FIG. 11—THE COLUMN WALL IN WOOD ALCOHOL REFINERY

been carried through successfully in more than one instance by the crude manufacturer, because of his advantageous situation, and it is certain that these attempts, therefore, to thwart the natural economic development of this industry will sooner or later collapse to a great extent, or the refiner will be compelled to either go into the crude business himself or combine with the crude manufacturer.

We have attempted to show the difficulties met and the expensive experimentation that has been undertaken in the past for the improvement of this industry, and have pointed out some of the results thus obtained. When it is remembered that German statistics claim that but one of fifteen serious trials of new chemical processes are successful and that this percentage amply pays for the losses entailed in the fourteen unsuccessful ones, it can be seen that while these expenditures are individually unfortunate, in the aggregate this law of averages will probably hold good in the development of this industry for its economic position demands the solution of the problems indicated.

Columbus, Ohio.

The Natural Chill of Cast Iron and its Significance in the Manufacture of Malleable Castings

BY GRAFTON M. THRASHER

Some years ago the author of this article became impressed with the growing need for more light on the subject of iron mixtures generally. All published articles on this subject laid heavy stress upon the adjustment of the silicon with more or less vague statements as to what the proper percentage should be in various castings.

Many very arbitrary and conflicting statements were made by different writers and investigators which were very confusing to one in search of fundamental facts.

During the intervening years much has been done to clear up what were once great mysteries to the foundryman, but it seems that while we have collected an immense amount of data, yet very little of it has been coordinated in such a manner as to make it valuable to the foundryman; and the mixing of iron, while practically all done by chemical analysis at the present time, is largely done by formula or pattern mixture without a definite knowledge as to whether it is the best suited to the work or not.

Several years ago while the author was engaged as chief chemist for a prominent and long-established malleable iron company, it occurred to him that the mere regulation of silicon was not sufficient to produce the desired degree of chill.

While the author has often noticed this phenomenon before in connection with cupola iron it was only after being repeatedly impressed with it in the case of both, open-hearth and air-furnace metal that it occurred to him that variations in the total carbon was the principal cause of disturbance and after some thought on the matter it was decided to run total carbon as well as silicon on every heat and by a carefully prepared test piece to gauge the approximate degree of chill. The test piece selected for this purpose was a round plug cast in green sand on end and was 2 in. in diameter and 12 in. long. The plug was allowed to cool at least two hours in the mold before being cooled in water and broken in the middle, and the fractures were designated as grey, low mottled, mottled, high mottled and white. From the same ladle of iron from which the test piece was poured a shot sample was taken for analysis so as to represent the actual iron in the bar as near as possible and the test in all cases was poured from iron taken from the furnace when about half emptied.

It may be well to mention here that the principal disturbing influence on these tests is the fact (proven by experiment) that it is entirely possible to pour a mottled test and a grey test from the same ladle of iron, depending upon the pouring temperature.

In order to study the cause of the variations more systematically a chart was prepared for plotting the analyses with carbon as ordinates and silicon as abscissa. By following up this idea it soon became apparent that the analyses corresponding to the test piece with average chill designated as mottled were arranged along a diagonal line on the chart with analyses corresponding to high and low chill at a more or less definite distance on either side of the line. It so happened about that time that a heat had to be held pretty long in the furnace on account of a break down and it became necessary to doctor it up with 50 per cent ferrosilicon to get the metal into pouring condition. When this heat was out the test piece was examined and found to be just normal or what is designated above as mottled and the analysis corresponding was found to be silicon 1.07 per cent and carbon 2.47 per cent, which served admirably for one

extreme of the chill line as drawn on the chart. In casting about for something to form a point for the other extreme it was found in the shape of a pig of charcoal iron of the same dimensions as the test piece and with the proper degree of chill.

More recently the writer has obtained data for a new high-silicon point in which the analysis was, silicon 1.25, carbon 2.25.

The chart as finally constructed took the shape illustrated in Fig. 1.

As the manganese in all of these heats ranged between 0.25 and 0.35, which is normal for air furnace malleable and as sulphur averaged about 0.06 it will be seen that these elements interfered but little with the results. The phosphorus, of course, was between 0.13 and 0.18 and also had very little influence.

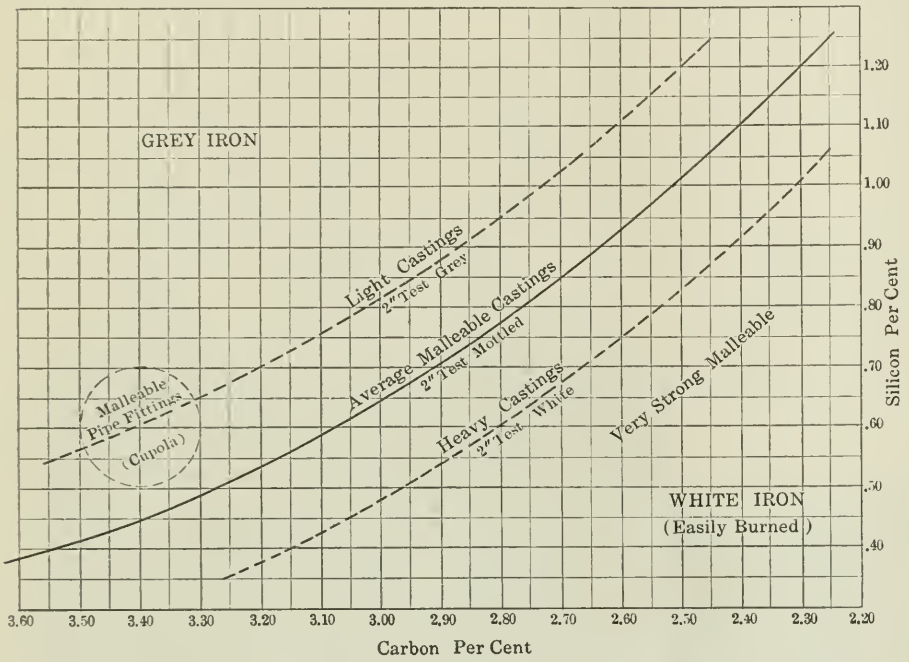


FIG. 1—LINES OF EQUAL NATURAL CHILL AND THEIR APPLICATION TO THE MANUFACTURE OF MALLEABLE CASTINGS

In examining the chart it will be noted that while the line tends to curve somewhat, yet it is sufficiently straight through the usual range of analyses so that for practical purposes we may assume that four (4) points of carbon are equivalent to three (3) points of silicon in the regulation of chill. When the silicon is above 0.70 per cent and below this about two (2) points carbon are equivalent to one (1) point silicon.

The value of this knowledge will be at once apparent to a malleable foundryman as it enables him to substitute large quantities of low-carbon material for his sprue in case of shortage of this material, thus:

It is desired to substitute steel containing silicon 0.10 and carbon 0.30 for 1000 lbs. of sprue containing silicon 0.80 and carbon 2.80.

Equivalent deficiency of silicon in the steel due to low carbon equals $2.80 - .30 \times \frac{3}{4} \times 1000 = 18.7$ lbs.

Silicon deficiency $= .80 - .10 \times 1000 = 7.0$

Total equivalent silicon deficiency $= 25.7$

Therefore, it is necessary to increase the silicon in the mixture by 25.7 lbs. through substituting higher silicon pig iron.

The popular conception of malleable iron accepts the limits of 0.60 to 0.90 in silicon and with a very indefinite idea as to what the carbon content in the hard state should be, but a careful examination of this chart will show that for a given silicon percentage there is a definite carbon percentage which is proper for each class of castings.

In order to prevent cracked work and for other economic reasons the malleable foundryman runs his mixture as nearly grey as he dares, but if he desires to produce a very strong iron the presence of primary graphite in the hard iron must be avoided either by lowering the silicon or the carbon or both.

As to malleable iron produced with the same average chill but with varying analyses it will be found that the high-silicon, low-carbon mixture is more sound and reliable, but it is possibly a little less fluid, while the high-carbon, low-silicon mixture is subject to greater shrinkage and segregation which produce weakness.

The principal consideration for the foundryman is to produce that type of structure which is necessary to obtain malleability upon annealing and the chart shows the proper adjustment of silicon and carbon to bring about the desired results for the different grades of work.

It will be further noted that, of the three factors considered, namely, silicon, carbon and chill, if any two be known the other may be predicted approximately.

Malleable iron produced from the cupola is pretty well confined to the dotted circle shown on the chart, its proximity to grey iron as well as its position in the field of greater shrinkage will account for its weakness, which is not due as popularly supposed to the higher sulphur content. As the carbon is automatically adjusted within this range by melting in the cupola the regulation of chill must be effected by silicon alone. It is not feasible, however, to run a mixture which is lower than 0.50 silicon as the cutting action of the slag produced is very hard on cupola linings. Good malleable castings are being produced along the whole length of the charted lines, but the average foundryman with his limited knowledge of conditions to be met in another foundry cannot see how the other party makes a certain casting with 0.90 silicon while he finds it necessary to make it with 0.60 silicon. It is hoped that the publication of this chart will clarify the matter. The lines here given have been confirmed by plotting hundreds of analyses of mixtures of known chill and normal pouring temperature and the chart has been found a valuable aid in practical work.

The writer desires to acknowledge the inspiration received from an article by Prof. Henry M. Howe written several years ago, in which he urged practical men to take up the study of some data already collected and help interpret its significance. He also wishes to express his appreciation to his late employers, Stanley G. Flagg & Co., of Philadelphia, whose works probably afford better facilities for the study of this subject as applied to malleable castings than any other single plant in this country.

Haskell & Barker Car Co.,
Michigan City, Indiana.

The Arizona Copper Co., Ltd., produced 1201 tons of copper in November, 1914.

Philadelphia Meeting of American Institute of Chemical Engineers

The seventh annual meeting of the American Institute of Chemical Engineers was held in Philadelphia from Dec. 2 to 5.

The opening session of the meeting was held at Hotel Adelphia on December 2 at 10:30 a. m., president M. C. Whitaker of Columbia University presiding. The Institute was welcomed to Philadelphia by Mr. E. C. Cattell, representing Mayor Blankenburg, in an address fairly sparkling with wit and humor. The importance of Philadelphia as a manufacturing center was brought out forcibly by the speaker.

During the business session the result of the ballot for officers was announced. Dr. GEO. D. ROSENGARTEN of the Powers-Weightman-Rosengarten Co. was elected president for the coming year. Prof. J. M. Stillman of Leland Stanford University, Cal., was elected third vice-president. G. W. Thompson, chief chemist of the National Lead Company, and A. C. Langmuir, superintendent of the glycerine refinery of Marx & Rawolle, being first and second vice-presidents. The following officers were also elected: Prof. J. C. Olsen of Cooper Union, New York City, secretary; Dr. F. W. Frerichs of Herf & Frerichs, St. Louis, Mo., treasurer; Prof. A. W. Smith of Case School of Applied Science, Cleveland, O., auditor, and Mr. Geo. P. Adamson, Dr. J. B. F. Herreshoff of the General Chemical Company, and Dr. Samuel P. Sadtler, directors.

The secretary reported 228 members, a considerable gain over the last report. The treasurer reported a very satisfactory financial condition of the Institute, a deficit of long standing having been wiped out.

The Committee on Chemical Engineering Education reported that arrangements were being made with the Carnegie Foundation for the Advancement of Teaching for co-operation in their investigation of the present status of engineering education.

GEORGE D. ROSENGARTEN, PRESIDENT AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

Prof. D. D. JACKSON of Columbia University read a paper on "The Manufacture and Application of the Artificial Zeolites (Permutite) in Water Softening," illustrated with lantern slides and samples of the products. The use of permutite for water softening was explained and a description of the process of manufacture given. Lantern slides giving views of the German as well as a factory in Brooklyn, N. Y., were shown.

Dr. A. S. CUSHMAN and Dr. GEO. W. COGGESHALL of the Institute of Industrial Research, Washington, D. C., presented the results of their investigations and experiments on the commercial extraction of potash from feldspar in a paper entitled "Feldspar as a Possible Source of American Potash." Several hundred tons of potash had been extracted from feldspar. Detailed estimates were given of the cost of a plant capable of handling 300 tons of feldspar daily, showing that potash can be produced from feldspar and sold at a profit. This paper will be published in full in our February issue.

On Wednesday afternoon the plant of the Atlantic Refining Company of the Standard Oil Company at Point Breeze on the Schuylkill River was visited. The method of distillation of the petroleum and especially the fractional condensation of the vapors and the method of control of the temperature of these condensers was examined with great interest.

The plant of the United Gas Improvement Company was also visited. The waste heat boilers were examined with great interest. The retorts are heated by a coke fire, which is fed by the hot coke from the retorts. The hot gases from the combustion of the coke after heating the retorts are carried through the tubes of the nearly vertical steam boilers. The gases enter the tubes at about 1200° F. and leave at about 350°.

On Wednesday evening at the Franklin Institute, Dr. GEO. O. SMITH, Director of the United States Geological Survey, delivered an address on the Distribution of Industrial Opportunities, showing the very widespread distribution of mineral and other natural resources in the United States.

Dr. JOKICHI TAKAMINE then delivered an address on the Chemical Industries of Japan, which include pottery, lacquer, cement, fertilizer, metallurgical and fermentation industries. By means of numerous lantern slides the old Japanese methods as well as modern up-to-date methods of manufacture were shown. A number of slides illustrating Japanese conditions of living were also shown.

On Thursday morning the plant of the Welsbach Works at Gloucester, N. J., was visited. The process of decomposing monazite sand with sulphuric acid, separating the thorium from the other metals and converting it into the nitrate was shown. The entire process of mantle manufacture was inspected, especial interest being shown in the solvent recovery plant where methyl alcohol, acetone and camphor were recovered and separated. The plating department was found to be very complete, nickel, brass and copper plating being shown as well as the production of a great variety of finishing coats and enameling. Brass casting and the manufacture of the metal parts of the lamps were inspected. After the visitors had been photographed a luncheon was served by the company.

During the afternoon a portion of the party visited the yards of the New York Shipbuilding Company, where several battleships are being built. The linoleum works of Farr & Bailey were also visited. The linseed oil was oxidized by blowing air into the oil and also by the older and slower method of exposing the oil to the air in a thin film on large canvas sheets. The oxidized oil was then melted with rosin and gum to produce the linoleum cement. The ground cork was mixed with the cement and coloring matter and applied to the burlap by means of steel rollers. The printing was carried out by means of flat plates, the various colors being applied successively and the finished linoleum suspended in long loops for drying. The manufacture of inlaid linoleums was also shown.

On Thursday evening a subscription dinner was held at Hotel Adelphia with about 50 in attendance. Past President Chas. F. McKenna acted as toastmaster.

Mr. Robert W. Leslie of Philadelphia, delivered a toast to the President of the United States. Mr. Cattell responded for the Mayor and delighted every one with his flow of humor and pathos.

Dr. Geo. D. Rosengarten, the new president, expressed his appreciataion of the honor conferred upon him.

Prof. J. P. Remington spoke of the many valuable services which Dr. Rosengarten had rendered for the advancement of the best interests of Philadelphia.

Prof. M. C. Whitaker urged the great importance

of greater frankness in the discussions of professional problems.

Toasts were also given by Prof. A. W. Smith, Mr. Wm. H. Bower, Dr. H. S. Miner and Prof. Wm. P. Mason.

On Friday morning a resolution was passed favoring San Francisco as the meeting place for the summer meeting of the Institute, the exact date to be fixed early in September by the Committee on Meetings.

A paper on "Hydrometallurgical Apparatus and Its Use in Chemical Engineering" by JOHN V. N. DORR was then read and illustrated by numerous lantern slides. The paper was a very interesting first-hand sketch of what the Dorr classifier, the Dorr thickener and the Dorr agitator have been able to do for the evolution of modern cyanide and general metallurgical practice. The application of the Dorr apparatus to analogous work in various chemical industries suggested itself. An interesting illustration of the increase in scale in modern metallurgical work in a Dorr classifier, 130 ft. in diameter and 6 ft. deep, of the Arizona Copper Company. The first part of this paper is published in full on page 55 of this issue.

Prof. JAMES R. WITHROW and E. H. FRENCH read a paper on the "Hardwoood Distillation Industry," in which they presented the growth of this industry and the gradual evolution of methods and types of apparatus and showed numerous slides of typical installations. The paper, which is published in full elsewhere in this issue (p. 30) was discussed in considerable detail by H. C. Chute and others.

Dr. BERNHARD C. HESSE emphasized in a paper on "Need of Up-to-date Manufacturing Statistics" the great need of recent and reliable statistics of domestic and foreign manufacture and urged the appointment of a Committee of Chemical Engineers to cooperate with similar committees of other technical societies in assisting the United States Department of Commerce in this work and especially calling attention to the needs of the chemical profession in this respect.

Friday afternoon the Commercial Museum was visited, where Dr. Wm. P. Wilson explained the work of the museum. The laboratories of the University of Pennsylvania were then inspected, the members of the Institute being received by Dr. Edgar F. Smith, Provost of the University. Members were very much interested in the old English chemical balance which had been used by Priestley.

Friday evening Mr. G. W. THOMPSON read a paper on "Causes of Paint Defects," in which he showed that many defects such as checking, cracking, peeling, etc., are due to faulty methods of application and not to any inherent defects of the paint materials. He showed that the yellowing of white paint is caused by alkalis and especially by traces of ammonia in the atmosphere. The paper was illustrated by lantern slides.

Mr. H. A. HUSTON of the German Kali Works, explained the methods in use in the German potash mines by means of delightful moving pictures. He also explained the methods in use for refining the crude ore.

Dr. EDWARD GUDEMAN, in a paper on "Aspects of Some Chemical Industries in the United States To-day," showed that it is entirely feasible to manufacture in the United States many of the chemicals needed at present.

On Saturday morning a large delegation visited the chemical department of the Barrett Manufacturing Company at Frankford, Philadelphia, Pa. At this plant the light and middle oils obtained by the distillation of coal tar are used for the preparation of naphthalene and carbolic acid. The oils are first fractioned by distillation and condensation in a column still. The naphthalene is allowed to crystallize out and separated by means of a centrifugal. The crude naphthalene is melted, allowed to crystallize and again separated by means of a centrifugal. It is then treated with sulphuric acid and distilled and the product sublimed. By means of a similar process pure carbolic acid is obtained. Various oils used for disinfecting purposes are also produced as by-products.

About 100 were in attendance at the meeting, which was very successful in every respect.

Dr. John C. Olsen, Cooper Union, New York City, is the secretary of the Institute.

Colorado School of Mines Short Course for Prospectors

To promote the more efficient prospecting of the mineral lands of Colorado, the Colorado School of Mines will establish a short course for prospectors, to be given at Golden, beginning February 8, 1915, and continuing for three weeks.

The work will include both lectures and laboratory studies involving the simple and ready tests for the detection of minerals in the field, as well as a consideration of geological formations favorable for various mineral occurrences.

No fees will be charged for this course other than a nominal charge to cover the cost of supplies used, which should not exceed $3.00.

The course is open to prospectors and others interested in the more intelligent prospecting of our mineral areas.

Electrical Energy Exported from Canada

Of the hydro-electric energy generated along the international boundary in Canada more is exported to the United States than is used in Canada, according to a report issued by the Dominion government. The total production of electrical energy in 1913 by Canadian companies with transmission lines extending into the United States was 1,543,464,097 kw-hrs., of which 772,597,049 kw-hrs. were exported and 770,867,048 kw-hrs. were used in Canada. The totals by companies are shown in the accompanying table:

KILOWATT-HOURS OF HYDRO-ELECTRICAL ENERGY EXPORTED FROM CANADA OR USED IN CANADA

	Exported from Canada	Used in Canada
Canadian Niagara Power Co.	400,214,908	1,1420,020
Ontario Power Co.	282,123,004	412,597,896
Electric Development Co.	42,154,000	191,885,670
Western Canada Power Co.	23,213,891	39,339,239
Ontario & Minnesota Power Co.	21,649,327	868,856

In addition a large amount of hydro-electric energy is generated by Canadian companies in the vicinity of Montreal, Toronto, Quebec and Winnipeg. This is not included in these figures, as none of it is exported.

Resolutions relating to copper as contraband of war were adopted by the American Mining Congress at its recent session at Phoenix, Ariz., appealing to the United States government "to use its great offices to keep open every available market for copper and give full protection to the producers of the metal in the shipment of same in neutral vessels to neutral ports."

An echo of the war is found in the statement that the South African School of Mines has been closed owing to the departure of students to join various units of the defence force. Those who have not been called have been employed by the Consolidated Gold Fields group of mines.

The Rand and the War.—From the *South African Mining Journal* we learn that the president of the Chamber of Mines feels that the position of the mining industry with regard to the war is satisfactory. "Ample supplies of cyanide, zinc and mercury seem assured, and further shipments are now coming forward." Prominent operators express the opinion that the gold industry in South Africa will not suffer.

Handling Iron and Cinder at the Blast Furnace

BY J. E. JOHNSON, JR.

In the early days of the blast furnace it was probably the custom to allow the iron to run out in puddles in front of the furnace and there cool, but soon this crude practice developed into making a runner leading away from the furnace and putting short lateral runners off from one side of it so as to mould the iron into convenient shape for future handling. The runner was rather crudely formed as were the lateral runners, which also were few in number.

The general appearance of the whole arrangement was roughly similar to that of a sow with a litter of suckling pigs, from that comes the name of pig iron, and to this day the runner from which the individual "pigs" are cast is known as the "sow."

In still later times as outputs grew the pigs were not cast directly from the main central runner, but this branched into lateral runners at right angles to its course, and from these, at right angles again and therefore parallel to the main runner, ran the individual pigs. The combination of the branch runner or sow and the pigs which go with it are known as a "bed."

This system of casting the iron persisted as practically the only method of handling it until very recent years. Even at the time of the "Duquesne Revolution" when nearly everything else about the furnace was improved almost past recognition, the handling of the iron was changed only in detail rather than in principle.

Casting in Sand Beds

The runner and beds were until about twenty years ago practically always made up in sand, since sand does not wash in a liquid with a high surface tension like a molten metal, and at the same time is porous enough to permit the gases generated by the action of the intense heat of the iron on the water and organic matter it contains to escape freely. This is a matter of the utmost importance because if such free escape through the sand is not permitted the gases generated will bubble up through the liquid metal when their pressure has risen above that corresponding to the depth of metal upon them, and when this pressure is reached the action is very rapid, because the head decreases as the gas rises, while the volume of the gas simultaneously increases, as it bubbles up through the metal.

The consequence of these ebullitions is that the sand is disturbed when the gas is released, and the hot iron is given access to wetter and fresher sand underneath, with consequent generation of more gases, and its release in turn with a still greater tendency toward violence. This action continues progressively, if it once gets started, until a "boil" results.

These are spectacles of impressive beauty, like magnificent fireworks, for those not concerned in their results, but are frightfully expensive, not only in the loss of iron, but in the difficulty of removing that which remains in the center after the boil is over.

The depth to which one of these boils will dig in a short time is almost beyond belief, and if one occurs close to the front of the furnace so that there is no room to deflect the iron above it, it constitutes one of the worst interruptions that can befall the operation of the furnace.

I have seen a mass almost wholly of iron, but with a little cinder on top, about the shape of a huge strawberry, six feet in height and more in diameter, taken out after a boil of only a few minutes duration, at the end of the iron trough. The difficulty of digging down to the bottom of such a boil and draining the liquid iron from the bottom of it is enormous, and a delay of hours in the operation of the furnace is practically certain to occur as a result of such a catastrophe in this location. For this reason the quality of the sand used in the pig beds, and particularly in the runner, is of vast importance. It must be coarse and open-grained, practically free from clay, and also free from lime, oxide of iron or any similar material which can unite with the silica at the high temperature of the iron and form a slag, and if such a slag be formed it will cause great waste of sand, dirty iron and a tendency to boils by sealing the pores of the sand beneath.

The first great change chronologically from this established method of handling the iron was the introduction of the mixer, of which, however, it will be more convenient to treat later.

Casting in Chills

Next to this came a change forced by the introduction of the basic open hearth process for the manufacture of steel. In this all silica introduced into the open-hearth furnace has to be slagged with lime of something like twice its own amount, which it is very likely to size from the bottom of the furnace, and so cause rapid wear of the latter as well as heavy expense in the consumption of lime.

For this process, therefore, some substitute for sand casting was found to be almost a necessity; this was found in the use of chill molds. These are virtually pig beds of cast iron which replace the ordinary sand beds and are fed from the central sand runner, the same as the original sand bed. These chills are not a modern invention. I have seen one which was made and presumably used at a charcoal furnace before the Civil War, but real need for sandless pig iron did not develop until the early nineties, consequently the chills, which are somewhat troublesome until the details of handling them are learned, never came into general use until then.

Certain irons, particularly hot irons, low in silicon, and made on a very limy furnace have the power of attacking and dissolving cold cast iron and burning to it. Obviously if this action took place to any extent the pigs would burn fast in the chills, and it would be impossible to remove them. To prevent this the molds are grouted with a solution of clay water soon after the removal of the cast from them, their heat then dries the water and leaves a coating of clay all over the chill. This is virtually infusible and serves to protect the chill from the action of the iron unless the latter is of an unusually cutting nature, when it sometimes burns fast to the chill in spite of the clay. Sometimes lime is used in place of clay, but clay is more easily held in suspension in water than lime, and is, therefore, more easy to apply uniformly.

These chills are exposed to enormous stresses. The whole bed of iron is obviously the same size as that of the chill at the instant of solidification, but as the iron cools off the chill absorbs its heat so that one gets hotter and the other colder. In order to get the cast out quickly it is customary to water it down with several hose nozzles as soon as the iron has solidified, and this of course throws still greater stresses upon the chills, but if the molds in the chill which form the pigs are of the proper shape and properly reinforced, they stand up very well under this treatment. It is necessary to have a considerable thickness of metal below the bottom of the pig, six inches is a minimum and eight is considered better. The bars between the pigs are known as the "cores," and including these the average thickness of the chill is from nine to twelve inches. The width of the chill in the direction of the length of the pig is over four feet and its length may be anything dictated by the size of the cast house and local conditions, but beds eighteen or twenty feet long are not uncommon.

A brief calculation will show that these must be very

heavy and in fact they weigh many tons. In some cases the beds are cast in several pieces, two or three, as this reduces the contraction strains and increases their durability, it also makes the individual pieces much easier to handle, although it is more troublesome to keep them in line with one another when made this way, unless longitudinal bolts are provided for holding them together.

Breaking the Iron

Each bed of iron when cast is obviously in the form of a huge comb and to render it merchantable this comb requires to be broken apart, and almost universally in foundry work the individual pigs require to be broken in two, this labor was in earlier days performed exclusively by hand. There are two ways of breaking, hot and cold. The former takes the least labor but is the hottest and the most disagreeable. It consists in catching the iron at the temperature immediately below solidification when it still has very little strength, and breaking the pig from the sow by the use of a crowbar applied under the junction of the two. The men wear clogs with wooden soles an inch thick, kept soaked in water when not in use, which are strapped to their shoes. A good deal of dust arises from the disturbance of the sand, while the radiation from the pig beds is very great in spite of the fact that a thin layer of sand is sprinkled over them, which cuts the heat down very greatly.

In the South where the conditions of atmospheric heat and humidity are relatively bad the custom has arisen of allowing the men to break the iron cold. The beds are watered down as soon as they are cooled below the point where sudden chilling will effect the fracture and appearance of the iron, the men then go on the beds with heavy sledges and crowbars and break the iron from the sow and break the individual pigs in two. This requires more labor and so is more expensive, but the work is more endurable for the men.

When the iron is cast in chills it is watered down and as soon as it has solidified the men work on it in pairs. One takes a short crowbar in each hand and pries up the point of the pig where its contraction has shortened it up so as to leave a gap of about half an inch between it and the chill. This man puts a heavy upward strain on this point with his hand bars, while his partner strikes a hard blow at the junction of the pig and the sow with an extra heavy sledge. This breaks the pig off from the sow and the latter is pried up and broken into two or three pieces by sledging after the pigs are all broken from it.

Casting the iron into chills instead of casting it in sand exercises a profound influence on its structure, particularly with irons low in silicon such as are required for the basic open hearth process and for which chills are used. If the iron be 1 per cent or over in silicon its fracture will be markedly different, when cast in chills, from that produced by casting in sand; it is much closer and finer grained, but the general nature of the iron is not much affected. But when the silicon gets down below 0.8 per cent, particularly if the sulphur be above 0.5 per cent, the iron begins to chill, and if the silicon drops still further it becomes perfectly white, very hard and excessively brittle. This is an advantage for steel making purposes since it has been proven that chilled iron melts more easily than the same iron not chilled, and therefore this facilitates melting down the iron in the open hearth furnace.

But for general foundry work casting in chills has only been introduced very slowly and after much missionary work among foundrymen who have very largely learned to judge the iron by its fracture and general appearance, an iron of open grain with large crystals being in general much superior from the foundryman's point of view to a close-grained iron with small crystals for general work. Therefore casting in chills converted good iron into bad from the foundryman's point of view, and if the silicon was a trifle low converted a really useful iron into one which foundrymen would not consent to use under any circumstances because it was "white."

This condition is gradually wearing away as foundrymen come to use analysis instead of fracture to judge the condition of their iron, but many merchant furnaces supplying the foundry trade still continue, and will for years to come, to cast their iron in sand.

The labor involved in these operations is generally not excessive measured in foot pounds of work performed, but must be done in a relatively short time to permit the cast house to be cleared for the next cast, therefore the men have to do the work under high pressure and under excessively disagreeable conditions owing to the heat and dust.

Pig Breaker

In order to overcome these hindrances to continuous and inexpensive operation the Duquesne furnaces were provided with chill beds, but they were also provided

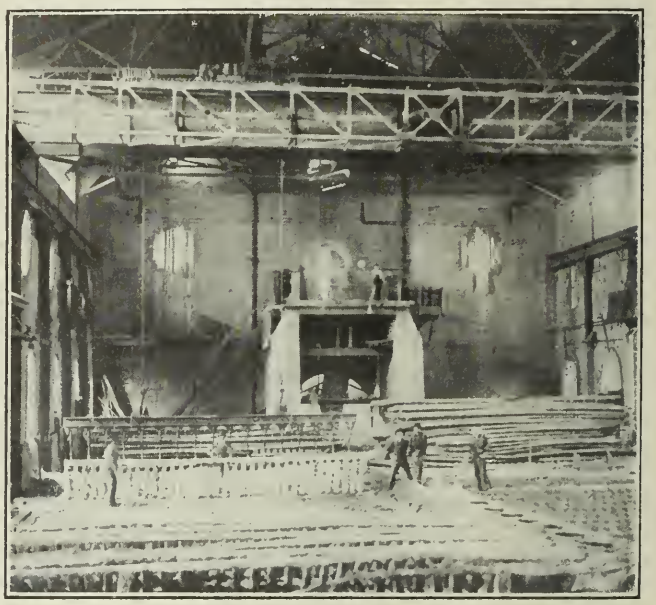


FIG. 1—INTERIOR OF CAST HOUSE WITH PILE OF PIG BEDS. CRANE LIFTING ONE PIG BED OUT OF SAND

with a crane in the cast house and the individual pigs were made vastly larger, both of heavier cross section and much longer than the ordinary pig, and were picked up by the crane which carried them to what was probably the first mechanical pig breaker. There they were laid down upon a table of rollers which fed them up to a hydraulic plunger working up and down which broke them into short sections.

Since that time the introduction of the crane in the cast house has become more general and should be universal. It is not only an enormous saving of labor in handling the iron, as I shall presently show, but is a convenience of incalculable value in times of breakouts, boils, putting in and taking out iron troughs, and assisting in the operation generally.

Since the time of the Duquesne Revolution the pig breaker has been much more highly developed, and in modern plants where pig beds are still used the handling of the iron is reduced to a mechanical operation.

The Brown Hoisting Machinery Company of Cleveland have developed the pig breaker in most common use, and through their courtesy I am able to show in Figs. 1, 2, 3, 4 and 5 the whole operation of handling the iron. In Fig. 1 there will be seen suspended from

the crane an I-beam carrying a number of heavy steel hooks. These hooks are lowered down over the bed and a couple of them are hooked under the sow and raise it onto blocks as shown in Fig. 2, in which position a fresh hold is taken of it with practically all the hooks engaged, the whole comb constituting a bed of two or three tons weight, may either be taken directly to the breaker in the rear or piled up as shown to the left of the breaker at the rear of the cast house. This is of particular convenience in case it is desired to have the analysis of the whole cast before breaking the iron and delivering it into the cars.

Fig. 2 shows the pig bed hanging from the hooks with its end entering the jaws of the breaker. It will be noted that the breaker is set at a high level, and in the center between the two piers on which it rests may be seen a chute leading out of the arch doorway at the rear. Into this chute the pigs drop as they are broken and slide into the car which takes them to their destination. The iron therefore is practically never touched by hand in any way until it comes to be unloaded at its destination, and while that is no part of our present concern,

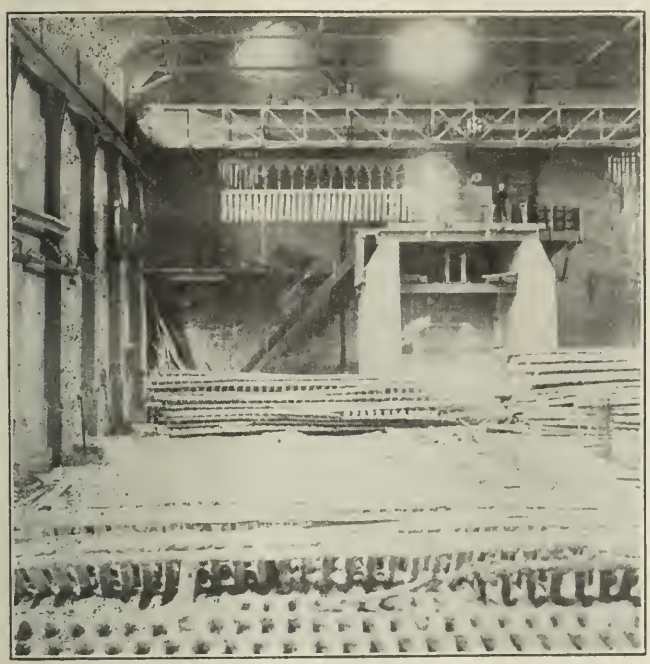


FIG. 2—INTERIOR OF CAST HOUSE WITH PILE OF PIG BEDS, ONE HANGING FROM CRANE

it is not amiss to say that that operation is now very generally carried on by huge magnets operated by cranes, so that even there no hand labor is required.

Figs. 3, 4 and 5 show the pig breaker itself. The vertical column at the left carries two horizontal plungers, one above the other, operated by hydraulic pressure. The column at the right acts merely as an anvil. In operation the comb is fed between the jaws by the crane; the first plunger is driven out against the top of the pig just where it joins the sow, and forces this over firmly against the anvil. The lower plunger is then forced out against the projecting bottom end of the pig, which it breaks off across the horizontal fulcrum seen about midway of the height of the anvil. This breaks the pig in two. The sow being supported by its top edge, with the bottom edge unsupported, while the end of the remaining portion of the pig is supported on the fulcrum, more pressure is then thrown on the top plunger, which is opposite the unsupported bottom edge, and this additional pressure breaks the pig loose from the sow, the sow is then broken into suitable lengths by proper manipulation of the position of the comb and of the pig breaker itself.

The hole in the floor just to the right of the operator delivers the pig into the top of the chute shown in Fig. 2. There is one of these on each side of the machine, so that no matter on which side the pig falls it reaches the same destination.

A pig machine has also been brought out by Mr.

FIG. 3—SIDE VIEW OF PIG BREAKER

James B. Ladd of Philadelphia, but the principle of this machine, while somewhat different from that of the Brown, is not so radically different as to require separate illustration.

The amount of labor saved by the introduction of this equipment is enormous. When it is realized that 500 tons is considered the normal output of a standard size furnace in the Lake Ore district, and that under the old regime this would have required to be broken by hand, then carried piece by piece and thrown onto trucks, by them carried from the cast house to the railroad car, and then thrown from the trucks to the railroad car, it will be seen that the labor involved was

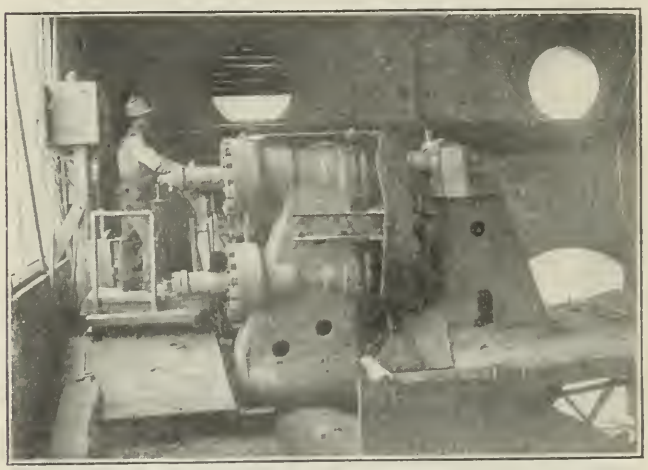


FIG. 4—PIG BREAKER, SHOWING HYDRAULIC CYLINDER AND ANVIL

tremendous and of the heaviest and most undesirable kind. Such labor is increasingly difficult to secure, and to handle, and the introduction of methods of handling pig iron by machinery is almost a necessity where it must continue to be cast in sand.

Molding Up Sand Beds

The beds were formerly molded exclusively by hand and still are in many cases. The sand is leveled off in the cast house floor, there is a pattern for the sow

and one for each pig, which are set down on the level surface thus prepared, the sand removed from the bed to level it is thrown back between the pigs and tramped to place to pack it, then struck off the top of the pig patterns, which are made with a considerable taper, these are then drawn by hand and thrown to the place for the next bed below, followed by the sow pattern.

This is probably the most laborious of any operation of considerable degree left around the blast furnace, and no means have been found as yet to reduce it to a very great extent, although where there is a crane in the cast house the pattern for the whole bed is made up in

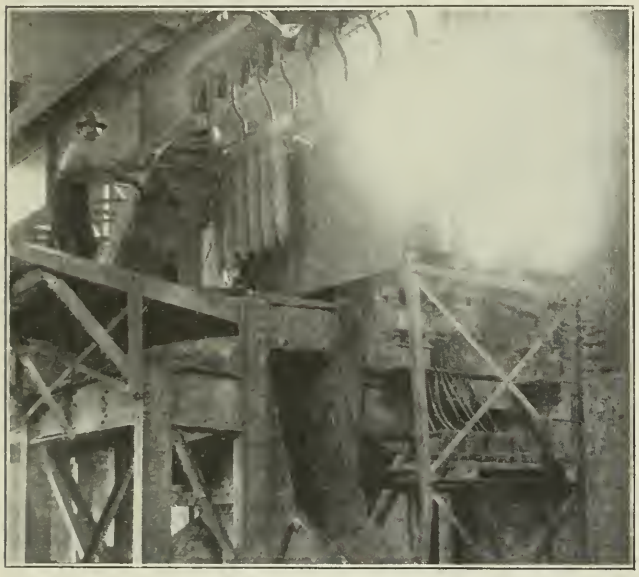


FIG. 5—PART OF PIG BED OR COMB IN JAW OF PIG BREAKER

one piece and handled by the crane; this saves a certain amount of manual labor, but so small a proportion of the total that the practice has been abandoned for the use of the old single patterns in some cases.

Various attempts have been made to reduce this labor but the sand has to be cut up with shovels after each cast has been watered down, not only in order to set in the pigs, but also because it is too much compacted by the wetting to provide the necessary free vent for the gases. This, with the necessity of having the beds nearly level with just enough fall to the sows and the pigs to cause the iron to run into them without overrunning the far ends, has made conditions too difficult to be met by machinery sufficiently simple and robust to perform the service in other particulars.

It seems not improbable now that the increasing use of the casting machine will eliminate sand casting entirely before mechanical methods are developed for molding the pig beds.

Handling Liquid Pig Iron

In the early days of the Bessemer Process, the first applied to the manufacture of steel on a great scale, it was customary to cast the iron at the blast furnace as described, take it to the steel works, melt it down into cupolas and then take it to the converters for conversion into steel. This was done so that an opportunity might be provided to analyze the iron and to make the mixture in the cupola suitable for use in the converters. This practice involved an enormous waste in two ways, first the labor of casting the iron into pigs as described above, and the disposal of the pigs; second, the labor and fuel required for remelting this in the cupola. This was accompanied by a very objectionable increase in sulphur from the coke used in remelting.

Many metallurgists sought to eliminate this double loss by using the metal direct, but furnace practice was not as regular and uniform in that day as it is now, and there was no certainty that the iron produced at one cast would be suitable for the converters because the last cast had been, and if the variation in composition were great the converter practice was completely upset.

The late Captain W. R. Jones, of the Edgar Thompson Works, solved the difficulty by the invention of the "mixer," a huge steel vessel lined with fire brick, mounted on trunnions and tipped back and forth for pouring by a hydraulic cylinder. The first of these had a capacity of 150 or 200 tons of iron, but later ones have capacities up to 600 and 800 tons.

All the iron from all the furnaces is poured into this mixer and that for all the converters is drawn from it. This provides a "cushion" to absorb the fluctuations in the quality of the metal and secures gradual variations of the metal delivered to the converter, which enables the converting mill to adapt itself to these changes without difficulty, while of course the mere fact of mixing the output of three or four furnaces necessarily reduces the average variation at least to one-third or one-fourth of that for any individual furnace, and generally much more.

Thus the mixer exercises two good influences. It greatly reduces the absolute size of the variations, and it makes them gradual instead of sudden. This improvement permitted the use of direct metal at the steel works, and practically all modern plants of combined blast furnaces and steel works operate on this system. Where steel is made by the basic open hearth process as well as by the Bessemer, a separate mixer is used for this iron, and the same advantages are secured in that practice.

The use of "hot metal," as it is universally called, for the steel works involved the necessity of having ladle cars to transport it from the blast furnace to the mixer and thence to steel works. These started out

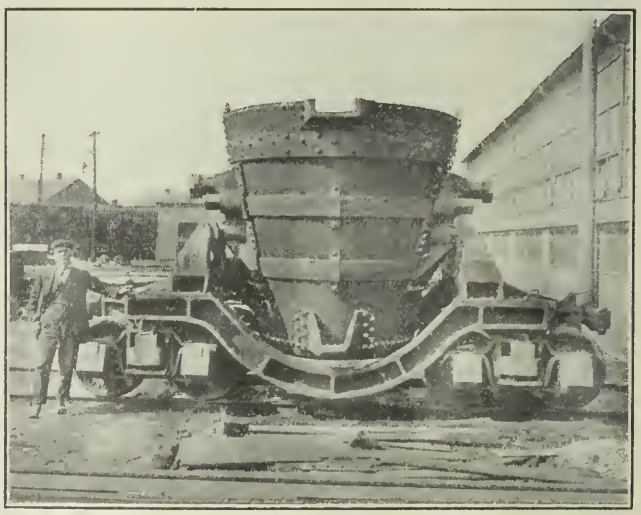


FIG. 6—POLLOCK HOT-METAL CAR

quite small, ten or fifteen tons capacity, but have gradually grown with the increased use of hot metal until 45, 50 and 60-ton ladles are now considered standard.

A ladle capable of carrying this amount of molten iron sometimes for distances of several miles, with entire safety from breakage of the apparatus or liability to accidental tipping, and yet capable of being easily poured where desired, is an apparatus of no mean proportions.

Such a ladle built by the William B. Pollock Company

is shown by Fig. 6. It will be noticed that this ladle is provided with five trunnions, two pairs below and a single one above on each side. It is also provided with a spout on each side and with a pocket for a hook at the bottom immediately under the spout to provide a convenient hold for the tilting mechanism. The single trunnions above are used in carrying the ladle on cranes; the two lower sets are used for pouring from the frame of the ladle car itself. The ladle revolves during the early part of the tilting movement around the forward one of the bottom pair of trunnions, but if it continued to revolve about this until empty its spout would be very low, necessitating a heavy drop for the metal poured at first in order to make room for the spout in its low position.

The purpose of the upper pair of trunnions with the corresponding jaws on the ladle truck shown beneath them is to prevent this low drop of the ladle spout, and it is obvious that when these upper trunnions reach a seat in the corresponding jaws on the truck the ladle revolves around them, the lower pair leaving their seats. This obviously throws the spout up much higher at the conclusion of the pouring operation. By this means the drop from the spout of the ladle is reduced several feet over what it formerly was, which is an advantage wherever it is used, but particularly in connection with casting machines to be described presently, of which the receiving end with the old style ladle had to be placed below the track, but with the style here shown,

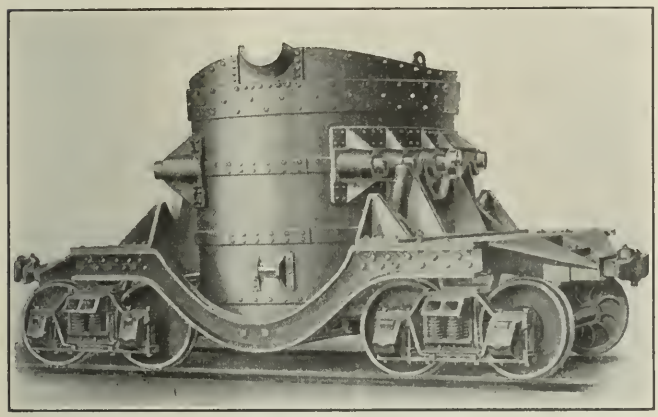


FIG. 7—TREADWELL HOT-METAL CAR

on account of the high position of the spout at the end of the pour, these machines can be raised above the track with the result of making them much more accessible and less expensive to install.

A hot metal ladle built by the Treadwell Engineering Company is shown by Fig. 7.

Casting Machines

The increase of furnace outputs during the nineties, of which I have spoken, required very large cast houses to take care of the iron, and the labor involved in breaking and carrying out these huge quantities of iron by hand was, as I have already explained, frightful. The entire plant depended upon iron carriers, since the furnace could not be operated unless the iron were carried out not *some* time but within a very limited period, so as to permit the beds to be made ready for the next cast. These conditions had the result of making this class of labor extremely hard to handle.

Conditions in this respect were, in one way, made worse by the growing use of hot metal at the steel plants, because it was necessary to have the iron carriers for Sundays and for emergencies when the steel works could not take the iron, while these men were not needed the rest of the time. This brought a demand for a mechanical means of taking care of the iron from the furnace. Casting machines had been in use at a much earlier period for copper, lead, etc., on a small scale, and under rather easy conditions, owing to the fact that the temperatures of those metals are far below the melting point of iron, so that iron molds could be used without great difficulty. But the case was quite otherwise with the blast furnace; the only material of

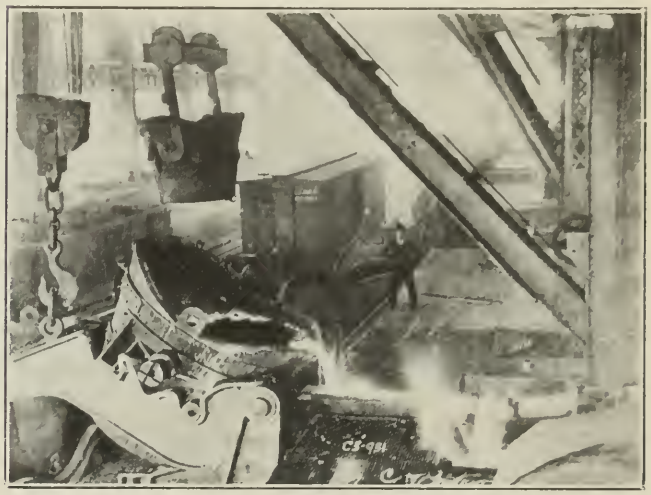


FIG. 8—HOT-METAL LADLE IN POURING CHAIN, POURING INTO BRANCHING TROUGH FILLING MOLDS

construction available was iron or steel, and the iron cast into either of these was likely to burn fast to them if they were not thoroughly protected, while if the metal was poured into them while wet violent explosions would result.

Various engineers attacked this problem, but the credit for the first successful solution belongs to E. A. Uehling, who designed a machine consisting of two endless chains in tandem. The first carries molds for the pigs into which the iron is cast, it is chilled by passing under a heavy spray of water on its course, then discharges at the terminal sheave onto the second chain, a conveyor of slats running for some distance under water, which cools the iron down to a temperature low enough to do no harm, this conveyor in turn discharg-

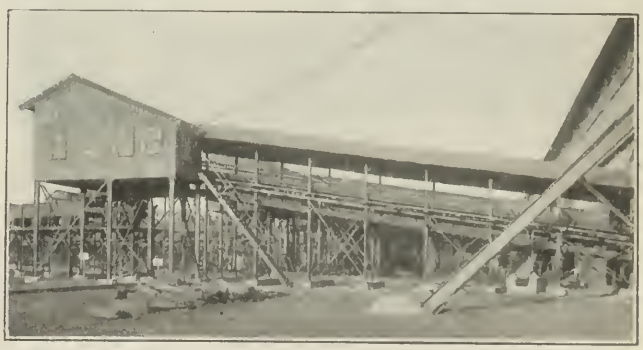


FIG. 9—FIRST OR CASTING CHAIN OF GROUP OF UEHLING MACHINES

ing onto the railroad cars which take the iron to its final destination.

Through the courtesy of the Heyl & Paterson Company I am able to show drawings, and an excellent set of photographs, of one of the largest installments of these machines ever built. Fig. 8 shows the ladle in a tipping chair which is elevated by the jib crane shown at the right and pours into a trough at right angles to the track, which branches both ways at its far end, each

branch pouring onto a separate strand of the pig machine.

Fig. 9 shows a general view of the ascending chain of the machine with the returning buckets on the under side.

Fig. 10 shows clearly a general view of the machines, the head houses where the casting chains discharge onto the cooling conveyors, the terminal houses from which the latter discharge into the cars, and the excellent ladder arrangement of tracks for serving the machines without the necessity of switching the cars under all of them to reach any desired car.

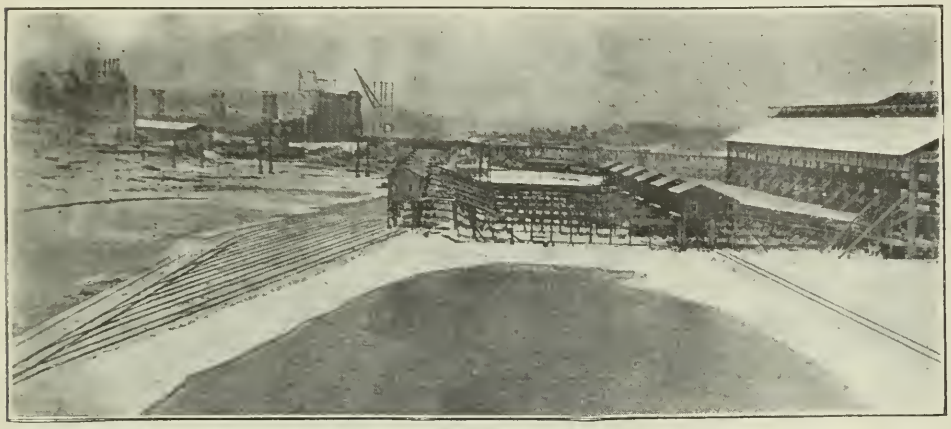


FIG. 10—GROUP OF UEHLING TYPE MACHINES

A view of the cooling conveyors with their water trough and the return side of the chain below is shown in Fig. 11.

The difficulty of having the metal burn onto the molds is obviated by having a jet of lime water from a tank underneath the return chain thoroughly sprayed up into the buckets as they pass over it on their return trip. The heat remaining in the mold causes the lime water to dry on it in a heavy white film, which of course is extremely refractory and prevents the contact of metal to metal, without which burning fast does not occur.

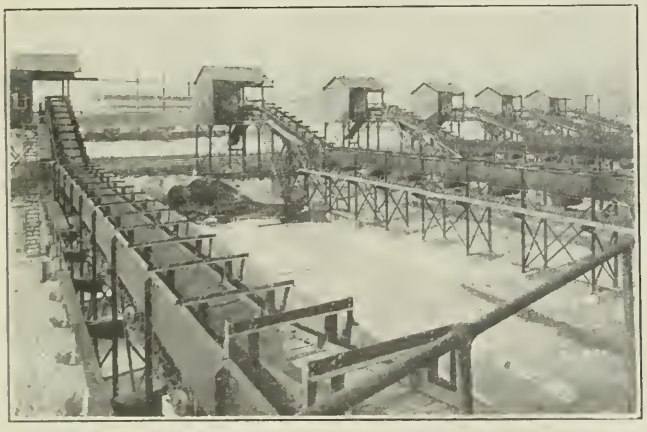


FIG. 11—COOLING CONVEYORS FOR UEHLING TYPE OF MACHINE. WATER TROUGHS EMPTY

Another type of machine was brought out about the same time in which the functions of both chains are merged into one. This was the design of the Heyl & Paterson Company, who now build both the Uehling type of apparatus and their own.

In this apparatus one chain performs both functions. The metal is cast into it at one end, it then passes down a slight grade into a long tank standing full of water where the iron is thoroughly cooled, rises out of this tank at a sharp elevation and is discharged over the end sheaves directly into railroad cars.

A photograph of an installation of this type is shown at Fig. 12, also by the courtesy of the Heyl & Paterson Company. Unfortunately the machine was empty at the time the picture was taken, but the molds show so clearly, also the way in which they pass under the water and out again and the overflow for keeping the water at the proper level that their action is perfectly obvious. A photograph of the same apparatus before the water was turned into the tank is shown in Fig. 13. The molds used in this conveyor are of steel, formed in a hydraulic press out of a piece of plate. They are subjected to terrific strains with the hot metal on one side of them and the cold water on the other, and after a certain amount of this service they lose their shape but can be repressed and restored to useful condition several times before they break from this treatment.

In some cases cast iron molds are used instead of steel. These of course fail by cracking and not by bending and are not capable of any further use after such failure. On the other hand they can be melted up and recast direct from the furnace in the floor of the cast house with very small expense, whereas when the steel molds once fail the loss is greater.

Both styles of molds have their advocates and both continue to be used after a number of years experience, so that the question of whether it pays better to use one kind or the other is probably very largely a local question.

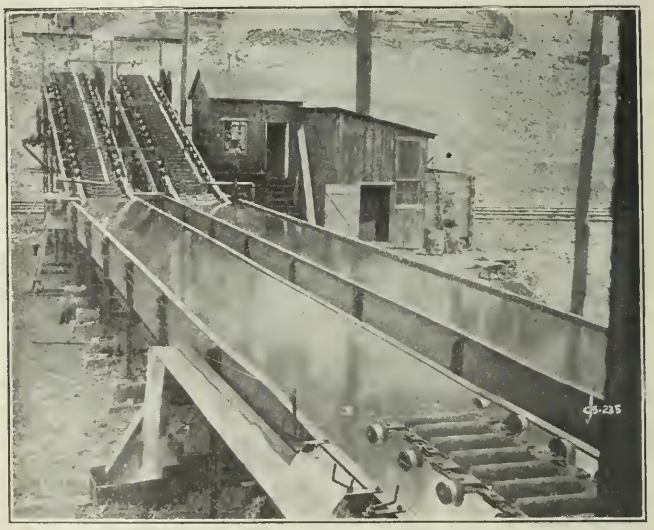


FIG. 12—HEYL & PATERSON TYPE OF CASTING MACHINE, STEEL MOLD SINGLE CHAIN, TROUGH FILLED WITH WATER

The merchant blast furnace isolated from steel wo ks will probably prefer the cast iron molds which it can produce from its own metal with a small amount of labor, while the steel works making steel plate and having available machinery for pressing the molds may find it cheaper to use the steel.

The introduction of casting machines of one type or

the other has become practically universal at blast furnaces directly connected with steel works, and even at many merchant furnaces. The huge cast house which was one of the prominent features of the blast furnace of former times has disappeared at such plants and nothing is left of it except a building large enough to cover the troughs in which the iron is run to the spouts above the ladles and to serve as a protection

FIG. 13—HEYL & PATTERSON TYPE OF CASTING MACHINE, STEEL MOLD, SINGLE CHAIN

against the weather around the base of the furnace itself.

Iron Troughs and Skimmers

A few feet of iron runner next the tapping hole has been used for many years, for the reason that if properly grouted and dried it is reasonably free from the danger of having the iron burn fast to it on one hand, and on the other entirely prevents unexpected moisture or other causes from producing a boil close to the tapping hole, because while a violent explosion is caused by molten iron running onto even the smallest wet spot on anything made of iron, it is prevented by the iron from burrowing deeper after each explosion, as it does when a boil starts in the sand.

A bad boil immediately at the tapping hole would prevent the shutting of the latter, and would put the furnace out of commission for an almost indefinite time and would constitute a catastrophe, therefore the iron trough is used to prevent this at all hazards.

Up to within a few years the runners from this point on were entirely of sand and the necessary arrangements for skimming the cinder from the iron were also built up of sand. The cinder has a specific gravity only about one-fourth to one-third that of the iron, and while the two come out of the tapping hole together during the latter part of the cast the cinder immediately rises to the surface and can be skimmed off without difficulty. To accomplish this the portion of the runner next to the iron trough is made very large relative to the portion below this point and a dam of sand some five or six inches high is put into the bottom of it four to eight feet from the iron trough; just above or in front of this is set a skimmer, formerly a thick plate of iron cast in open sand in the floor of the cast house, and guided by two pairs of pins driven into the sand of the runner on each side of it. When the cinder begins to show on the iron this skimmer is driven down with a hammer until its edge projects below the surface of the metal sufficiently to prevent the head of cinder floating on the iron from pushing under it, the cinder then rises and flows over a lateral dam, a low place in the side of the sand trough, and is led from there to its point of ultimate disposition.

With large and rapid streams of iron which were the consequence of the growing outputs of the nineties, this operation became more difficult and less certain. Either cinder was allowed to get down onto the iron, which created a fearful nuisance as the cinder broke off when the iron was cold and fouled the pig beds, or the iron itself would be forced out over the cinder dam and wasted. Moreover there was left in the basin formed by the iron and cinder dams at the end of the cast a considerable volume of iron with a heavy layer of cinder on top of it. To direct this iron to its proper place and keep the cinder from following it was by no means an easy matter, and much iron was likely to be lost in the cinder without the most careful practice.

In order to overcome these difficulties Mr. Michael Killeen at the Edgar Thompson works devised the Killeen skimmer. This consists of an additional section of iron trough linked to the section next the furnace. It has cast with it the cinder and iron dams, a slot in which to set the skimmer (preferably made of firebrick in an iron frame to prevent its cutting away during the cast, as the old iron skimmers did), and a supplementary lateral outlet extending clear to the bottom of the trough and closed by an iron gate with a loop in the top. Before cast this gate is set to place and the point between it and the body of the skimmer trough well protected with sand and grout. With this arrangement the skimmer can project far enough below the surface of the iron to prevent the possibility of cinder getting down the iron runner, while at the same time the cinder dam can be raised so high as to prevent the iron from rising over it and running to waste. The considerable volume of iron remaining in the trough at the end of the cast is released by withdrawing the supplementary lateral gate and allowing the iron to run into a special runner which takes it either into a ladle or to a special bed set below the level of the other beds as may be preferred. The cinder is prevented from following it by a hand gate dropped when the iron is all discharged and before much of the cinder can follow. This not

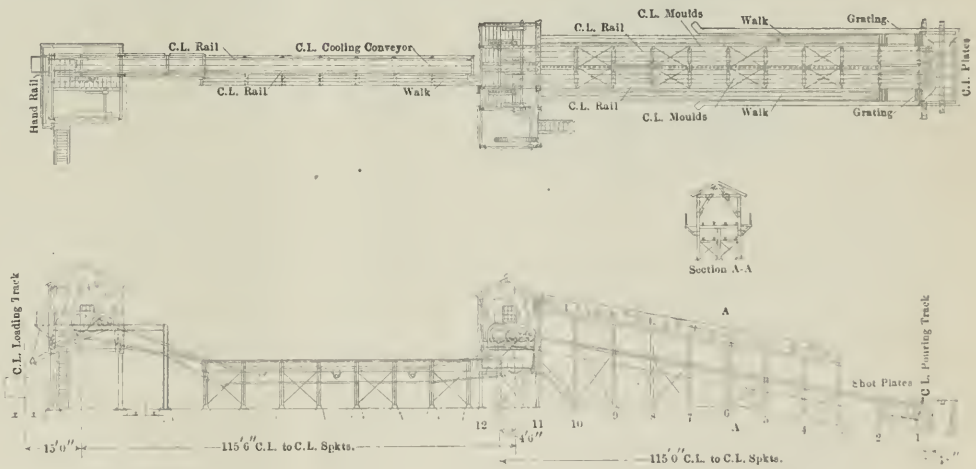


FIG. 14—GENERAL ARRANGEMENT OF UEHLING CASTING MACHINE

only prevents the iron from being wasted and the cinder from getting down the iron runner, but also drains the iron trough effectively to the bottom so that easy access is thereby afforded to the tapping hole in order to stop it.

Other forms of skimmers have since been brought out, but are only variations of the general principle of the Killeen design.

Following the introduction of the iron skimming trough iron runners were substituted for the sand runner all over the cast house. These are provided with grooves into which gates are set to cut off the flow of the metal, and are grouted after each cast with a mixture of sand and clay kept hot by a steam coil, the gate grooves being filled up flush with this mixture. With good practice only a very light skull of iron is left in these iron runners when the cast is over, and the runner requires only a new coating of sand and grout to make it ready for use again.

On account of its smoothness and uniformly sloping bottom the iron runner drains itself better than the sand runner, which prevents the formation of any but light scrap; moreover, with the iron runner it is possible to raise a gate which has once been set and allow iron to flow again down a section of trough from which it had been cut off, which it is never safe to do with sand runners because the withdrawal of the gate from the sand is extremely likely to cast a boil. These advantages have resulted in the universal introduction of iron runners where the iron is run direct to the ladles and not cast in sand beds.

(*To be concluded in February Issue.*)

Chemistry and Lighting

The New York Section of the American Electrochemical Society opened the season by a session at the Chemists' Club on the evening of November 10, devoted to a symposium of papers on contributions of chemistry to illuminating engineering. The meeting was held in co-operation with the American Illuminating Engineering Society and the American Gas Institute. The chairman of the New York Section of the American Electrochemical Society, Dr. Colin G. Fink, of the Edison Lamp Works of the General Electric Company at Harrison, N. J., presided.

COLIN G. FINK, CHAIRMAN NEW YORK SECTION AMERICAN ELECTROCHEMICAL SOCIETY

Introductory Remarks of Chairman

Dr. **Colin G. Fink,** in his introductory remarks, said that in the development of new and better forms of illumination chemistry has played a most important part. "For many decades the element carbon has been the basis of the best illuminants, whereas to-day we find investigations proceeding in three distinct lines: rare earths, rare metals, and rare gases. Professor Nernst and Baron Auer von Welsbach are among the most noted exponents of the rare earth investigations which have led to the Nernst glower and the modern incandescent gas mantle. Few of us realize that the modern electric arcs embody chemical problems which are only partially solved.

"And yet the very best and most efficient forms of lighting of to-day realize but 6 per cent of the energy, 94 per cent being lost as heat. The very best minds in America and abroad are striving and seeking to produce a light as economical as that of the firefly, whose little 'lamp' 'burns' at an efficiency of 98 per cent."

Chemistry of the Incandescent Gas Mantle

Dr. **H. S. Miner,** chief chemist of the Welsbach Light Co., Gloucester City, N. J., presented the following paper:

In responding to the invitation to tell you some of the new developments in the chemistry of the incandescent gas mantle, I very much fear that my hearers will be doomed to disappointment if I am expected to describe some startling change that has taken place in that industry. Since the wonderful and spectacular invention of the brilliant Austrian chemist, Dr. Karl Auer von Welsbach, who about thirty years ago produced the incandescent gas mantle which in all justice bears his name, the growth of the industry has been marked by steady improvements rather than revolutionary changes, unless indeed we are to include that radical change in the composition of the mantle body which Dr. Auer himself made, when in the early nineties he substituted the thorium-cerium mixture for the more complex lanthanum-zirconium-cerium mantle which had comprised his first commercial mantle body. This was indeed a radical improvement, and it marked the beginning of the general adoption of the incandescent gas mantle.

I have said that the days of *radical* developments seem to be in the past, and yet I never cease to wonder at the phenomenon of the change or petrifaction of the vegetable or organic fiber, reproducing the cellulose fibre in mineral form under the influence of the Bunsen flame and giving the light-producing body with which we are familiar. And although we hear the fragility of the mantle frequently alluded to, yet when I watch its formation in this manner, which seems to be essential to its light-giving efficiency, the strength and resiliency of the mantle is a "nine days' wonder" to me.

This change in the composition of the Welsbach mantle when the mixture of 99 parts of thoria and 1 part of ceria was substituted for the earlier mixture, has ever been to my mind an invention of the highest type, involving as it did the purification of rare earth materials beyond the limits of previous knowledge, and then the development of commercial processes for the

production of these rare earths in the highest state of purity.

Notwithstanding the extravagant claims made by many *pseudo* inventors, the thorium-cerium mixture still holds as the essential composition of all Welsbach mantles, and this, and this alone, is the basis of the light-giving qualities of the incandescent gas mantle; although the last quarter of a century has brought us much enlightenment upon the field of rare-earth chemistry, no satisfactory substitute has been found for this early invention of Dr. Auer's. An intimate knowledge of this industry from the very days of its infancy leaves me with an ever-increasing respect for the work of the pioneer, Dr. Auer.

In justice to the faithful and meritorious work of the many rare-earth chemists throughout the world, I would say that their work has resulted in certain changes and improvements in the mantle and burner which have decreased its cost and increased its efficiency and durability. Some of these points I will endeavor to touch upon.

In the early days a purified cotton fabric was saturated with the thorium-cerium mixture made of materials of as high a state of purity as possible. The purity of the cellulose was found to be absolutely essential, and the well-known bleaching and washing processes were carried beyond the point previously thought to be necessary, and a cotton carrying less mineral substance than the best absorbent cotton was soon produced. Realizing the deleterious influence of foreign substances, such as silica, lime, magnesia, alumina, phosphoric acid, etc., it was recognized that it was just as harmful to have these elements brought to the mantle from the vegetable fibre as from the rare-earth mixture.

It was early recognized that the length of the fiber or staple of the mantle fabric had much to do with its physical strength and its durability. Long staple cottons were used exclusively in the best grade of goods, and the longer fibered ramie or China grass was looked upon with favor when it was first introduced, but it was not used with any success by mantle manufacturers until it had been successfully de-gummed, bleached and washed. The accomplishment of this complex and difficult problem resulted in the adoption of ramie as a mantle fiber first in Germany and then in other countries. The adoption of ramie fiber made possible the mantle of the inverted or pendant type, which has since been so generally adopted.

Although the staple of the fiber had been increased in length from 1½ or 1¾ inches to 5 or 6 inches by the substitution of ramie for Sea Island cotton, and that with certain advantages, especially in inverted mantles, yet the ideal had not been reached, and it remained for the artificial silk or artificial cellulose fibers to supply that ideal. The delay in the development of the artificial silk industry caused a delay in the adoption of artificial fibers as a mantle-making body, but its many striking qualities of strength, elasticity and maintained candle-power have caused a persistence of effort that now had its reward in the arti-fiber mantle.

In the early days the only digressions from the ideal composition of 99 per cent ThO_2 to 1 per cent CeO_2 were slight variations in these figures within narrow ranges to produce lights with varying degrees of whiteness, an increase or decrease of ceria increasing or decreasing the yellow color of the light produced. The coming of ramie fiber and the inverted type of mantle made the introduction of small percentages of hardening materials essential, and beryllium oxide was found to be an ideal substance for this purpose.

The change of fiber and of the type of the mantles as indicated has caused a complete revolution in the processes of manufacture, and notwithstanding the experience already gained, each one of these changes has called forth a line of research that had made persistent work over a period of years essential before the problem could be considered solved. This is especially true of the arti-fiber mantles, and the changes in manufacturing processes have extended to the collodion or lacquer used to strengthen the mantle for transportation, for the collodion used on the cotton or ramie mantles was found to be entirely unsuited for arti-fiber mantles.

The problem of primary importance for the chemical engineer, as related to this industry, has ever been the manufacture of thorium nitrate, and many changes in the commercial production of this substance have, of course, been effected during the score of years just past. Monazite sand has always been, and still is, the only commercial ore from which thoria could be obtained, and contains from 5 to 6 per cent ThO_2; although small deposits of thorite and thorianite with a thoria content of 50 per cent and 75 per cent respectively have served to keep alive within us an appreciation of, and longing for, a more ideal ore as a source of supply. The high price of monazite—this very low-grade ore from a thoria standpoint, with nearly 95 per cent waste—has thrown upon the thoria content, while still locked up in this phosphate rock, a heavy burden of expense and has made necessary the production of high yields and low costs of operation to keep the cost of thorium salts low enough to make them commercially available.

The first processes used in factory practice were naturally but enlargements of the well-known laboratory methods of analysis, while from this beginning have developed modification after modification, substituting cheaper and cheaper reagents and methods of manipulation until the commercial processes of to-day hardly bear even a "family resemblance" to the first process employed. These modifications are, of course, still continuing, and are made imperative by the fluctuation in price either of the ore, of some reagent, or of the price of labor. But although there be variations in processes, there must be one unvarying standard ever before the chemist in charge and all of his associates, and that is the absolute purity of the product. Pure thoria is vitally essential, and I am gratified to be able to say for the thoria manufacturers of the world that their product is of very high grade and is better now, notwithstanding the cheapening and shortening of processes, than it was in the beginning, although even then it was sincerely labeled "C. P."

There are various means, both chemical and physical of checking and determining the purity of the product, but in the light of experience the most satisfactory method for both accuracy and rapidity is the manufacture of mantles from the thoria as it progresses in purity. The color of the mantle body, the color of the light produced, the presence or absence of shrinkage, the brittleness or flexibility of the mantle give to the experienced manufacturer a more satisfactory indication of the purity of the product than do the chemical analyses, which are of necessity long and tedious.

The other essential material which must always accompany thoria is ceria, and although it is used in only about one one-hundredth the quantity as thoria, yet its chemistry is just as important and its purity just as essential. I am glad to say that this product is even purer than when Dr. Auer first used it even in larger proportions in his lathanum-zirconium-cerium mantle. The oxide of cerium then obtained was of a reddish-brown tint, while that now manufactured is of a light yellow color, the former product having been slightly contaminated with neodymium, the last traces of which were difficult to remove.

By way of variety, and in order to add zest to the

work of the mantle chemist, he has also to manufacture beryllium, zirconium and neodymium, each of which he uses in a limited way, and none of these substances are really easy to produce.

Radio-chemistry has recently thrown the thoria manufacturer into the "lime-light" because of a radio-active product three hundred times stronger than radium, which occurs in and is produced from the thorium which he manufactures. I refer especially to meso-thorium, which a suffering and stricken humanity has implored the thoria manufacturers of the world to save for them, and which these manufacturers are now unitedly conserving as a substitute at least for radium.

With the possible exception of the meso-thorium just alluded to, every problem we have mentioned has a bearing upon the characteristics and qualities of some or all types of incandescent gas mantles. There is another and no less important problem, however, that should be alluded to, and that is the protective coating that must be applied to a finished mantle to strengthen it temporarily for transportation. In the early part of 1888 we were dipping the finished mantle in an alcoholic solution of shellac, made slightly flexible upon drying by the addition of a little castor oil. Some essayed to strengthen the mantle by the use of paraffine, and I have in my collection of curios a mantle imbedded in a cake of paraffine, which was to be removed by the melting away of the paraffine wax.

The invention of solutions of nitro-cellulose or soluble cotton opened up a new field of research, and the knowledge gained of the many various forms of nitro-cellulose and the numerous solvents therefor, together with the knowledge and control of such characteristics as viscosity, hydroscopic effects, etc., have made it now possible to prepare collodion solutions of almost ideal qualities for mantle purposes.

And what are these ideals? A collodion must be of the proper viscosity for mantles to be dipped in and withdrawn from it without rupture or strain; it must dry quickly with a film stiff enough for the mantle to be handled with safety, and yet strong and elastic enough to resist handling and shock; it must burn off slowly enough to prevent the mantle from becoming annealed or softened, and yet it must not leave the mantle body sticking to the cap of the burner. A collodion which answers these ideal characteristics is now realized in a nitrocellulose solution in a mixture of solvents with camphor made flexible chiefly by the use of castor oil.

I said in the beginning that the type of spectacular developments in the incandescent mantle industry were apparently over. At the close of this very general review I am, however, strongly tempted to modify this statement, and to class the commercial development of the arti-fiber or artificial silk mantle in this class of achievements.

The mantle manufacturer has held before himself for a quarter of a century and more certain ideals towards which he has earnestly striven. Some of these have been strength with elasticity, high and maintained candle-power, preservation of color and absence of shrinkage. A realization of these ideals seems finally to have been met in the mantle made from the bundle of elastic, spring-like fibers known as artificial silk, for the strength of these mantles certainly is something phenomenal, the high initial candle-power is not only maintained, but is frequently *increased*. This is made possible by the practical absence of shrinkage upon prolonged burning and by the very curious phenomen that this mantle does not seem to collect the fine mineral dust from the atmosphere as do those manufactured from the shorter vegetable fibers, cotton and ramie, this silicious dust having a very great affinity for the basic materials of the mantle body.

The attainment of this ideal has been reached only after years of persistent research guided by many more years of experience in mantle manufacture. Old theories had to be abandoned and former methods completely changed before this mantle was commercially possible. This was a chemical problem of great complexity, and its successful solution arouses such enthusiasm within me that I am tempted to include this among the radical and spectacular developments in our industry.

I have described some of the chemical problems connected with the manufacture of the incandescent gas mantle. There are many more that have to deal with the detailed process of manufacture of the mantle itself and with the economics of the industry, such as the conservation and recovery of waste products, but I will not weary you with a highly specialized paper. My chief excuse for treating the subject as I have done is to make it clear that each new type of mantle that is developed is an independent chemical problem from the beginning with the fiber of which it is formed, through every process and stage of manufacture, to the special collodion with which the finished product is finally prepared for transportation. I hope I have also convinced you that chemistry is just as essential for the successful operation of the incandescent mantle industry as it was in its inception and development.

Chemistry of Flaming Arc Carbons

Dr. **William C. Moore**, of the National Carbon Company, of Cleveland, Ohio, then presented the following paper on "Chemistry in the Development and Operation of Flaming-arc Carbons." The paper was fully illustrated by experimental demonstrations. We herewith publish it in full:

In an arc struck between two carbon electrodes, very nearly all the light comes from the incandescent electrode tips. In a direct-current arc, the positive crater is larger, and possibly at a higher temperature than the negative crater, and it is this positive crater which is the source of most of the light. Since the crater is merely an incandescent solid, it affords a continuous spectrum. Colorimetric experiments recently made by L. A. Jones and reported by him at the Cleveland meeting of the Illuminating Engineering Society, September, 1914, show that this incandescent crater has about 67 per cent of the daylight value of noonday sunlight. When volt-ampere readings are taken with such an arc it is found that if the arc is strengthened the voltage rises and the amperage falls, and eventually the arc goes out.

If we use as one of our electrodes a carbon rod which has been hollowed out into a cup, and place in the cup some potassium chloride, and again strike the arc, we find that the volt-ampere characteristics are changed and that at the same amperage a much longer arc can be drawn. Cassellmann in 1844[2] seems to have been the first to have noticed this fact. As we see, an arc fed with potassium chloride gives very little light; in fact, probably less than the pure carbon arc, as the positive crater is not so bright. This arc has a distinctive color, and, of course, would show, beside the carbon arc lines, the potassium lines in the spectroscope. Bunsen[3] in 1844 seems to have been the first to notice that different materials give different spectra in the arc.

If, instead of potassium chloride, we place a small amount of calcium fluoride in the hollow carbon cup, which, in this as in the previous case, is in the lower positive carbon, we find that the arc length for a given current and voltage is much shorter than for potassium chloride, and longer than for a pure carbon arc; moreover, the arc is intensely luminous, though rather un-

[2]Pogg. Ann. 63,576 (1844).
[3]Berzelius, Jahresbericht über die Fortschritte der Chemie und Mineral., 25, 20 (1845).

steady and liable to go out. On placing a mixture of potassium chloride and calcium fluoride in the arc, we get the combined advantages of a *long* arc, with more intense luminosity than is afforded by either the pure carbon arc or the potassium chloride arc alone. These simple facts form the starting point in the development of the modern flaming arc.

About 1899, Bremer, in Germany, brought out a flaming carbon, with calcium fluoride as the essential light-giving salt. The light afforded by such a carbon is a sensation yellow; the color is more aptly described, however, as "minus blue," as the spectrum of such an arc is very deficient in the blue.

From 1899 to the present the development of the flaming arc has been going on steadily and surely. It is interesting to note that the first record the National Carbon Company has of any work being done by them on the subject was when some ordinary cored carbons flamed and experiments were undertaken to prevent this phenomenon.

Although Bremer produced a carbon which could be burned vertically, for a number of years most of the commercial lamps were "inclined trim" lamps, taking long, cored carbons, which burned under open-arc conditions. A few years ago, however, there was developed a lamp for burning flame carbons in a vertical position, and for these lamps solid carbons have been developed. An interesting point is that the idea of solid carbons antedated the development of the lamps. These lamps generally operate in such a way that a limited supply of air reaches the arc; that is, under "enclosed-arc" conditions. These various types of lamps are doubtless familiar to the illuminating engineers present.

Modern flame carbons may be classified in several ways. From the standpoint of the mechanical structure of the finished carbon, we have cored carbons and solid carbons. From the standpoint of the color of the light emitted by the carbons, we have a major division in which are included yellow flame carbons and white flame carbons, and a minor division including red, green and blue flame carbons, red and green being but little used except for advertising purposes, and blue being used as a source of blue and ultra violet light for medicinal purposes.

In the major division, calcium fluoride is the chief constituent of yellow flamers, and rare earth compounds the chief constituents of white flamers.

A brief description of the method of manufacture of flame carbons may not be out of place. The first step, of course, is the careful weighing out of the requisite amount of the carbon base, and the proper flame materials for making a "mix." Most of these mixes are rather complex. After weighing, the ingredients are very thoroughly incorporated together and with an appropriate binder—generally tar, or pitch or a mixture of these. The "mix" is then forced by means of a hydraulic press, into long rods, which after cooling are cut into the proper lengths. These green carbons are then carefully baked in gas-fired furnaces and the temperature gradually raised according to a definite schedule, the final temperature attained being determined by a number of factors, such as the liability of some of the constituents to volatilize, or to react with each other and the carbon.

After cooling in the furnace, the carbons are unpacked, sorted, cleaned and gauged, the latter process consisting in determining the diameter, as but small variations in diameter are permissible; the carbons must also be quite straight. Some solid carbons are electroplated with copper, on the holder end to make a better contact between the lamp holder and the carbon. After plating, they are dried and made ready for shipment.

It is, of course, necessary to keep all flame carbons dry, as water may cause reactions between some of the flame materials, or may set up on a carbon-copper cell with some of the soluble or partially soluble salts as electrolytes and thereby destroy the copper coating. Water has another detrimental effect as shown by W. R. Mott[4], namely to react with the carbon at high temperatures, forming carbon monoxide and hydrogen; the latter may not only accumulate in the lamp housing and cause the lamp to explode when started again, but rapidly conducts heat away from the burning arc and lowers its efficiency.

The manufacture of cored carbons is quite similar to that of solid, except that the carbon base is different, and in forcing the die contains a pin which makes the carbons hollow. After baking, sorting and gauging this core hole is filled with a mixture of a carbon base and the flame materials with an appropriate binder, and the carbons are then dried. As cored carbons are usually very long and of small diameter, a zinc wire is inserted into a small hole parallel to the core hole. This wire increases the conductivity of the carbon. In order to make a good contact with the carbon and the holder, the carbons are "silver tipped"—that is, first copper plated, then dipped into solder, which solders the zinc protruding from the holder end, to the carbon. Such a connection is a permanent one, and is far superior to the scheme of simply bending the zinc over at the end of the carbon as the zinc becomes brittle when the core is dried and is liable to break off.

We now come to the question of desirable operating characteristics for a flame arc carbon. First of all, such a carbon should be reliable. It has been pointed out by Steinmetz[5] that after high efficiency is attained, we can afford to sacrifice some of the efficiency for reliability and other desirable factors. As will be shown below, the flame arc is already of high efficiency, hence we place reliability as our first desirable characteristic.

We may consider reliability under the four heads:

1. Constancy of distribution.
2. Constancy of light flux.
3. Constancy of color.
4. Ability to start with cold points after the carbons have been in use.

The length of the arc has a great deal to do with the amount and distribution of light. As the arc lengthens, the voltage increases; it is stated by Hechler[6] that there is a maximum definite voltage for maximum efficiency, that is, some definite arc length gives the most light.

The part that chemistry has had in increasing the reliability may be briefly indicated. It is readily seen that a flame arc which burns brightly part of the time and dimly part of the time can hardly be said to have 100 per cent. reliability if all the other factors are high. It may happen that all the flame material is evaporated from a given spot on the surface of the carbon, thereby causing a pure carbon arc for a short time. Such changes, however, are now rare, as a great deal of constructive chemical work has practically obviated this feature. As another factor affecting the reliability of operation of flame arc lamps, is the formation of slag on the points or on the lamp mechanism, it is readily seen that the proper proportion of the flame constituents and the right kind of addition agents for preventing such slags are of great importance, and here again we find that extended chemical research has resulted in the development of carbons in which this source of trouble has been largely overcome.

[4]Mott, *Electrical World*, Dec. 13, 1913, p. 1220.
[5]*Gen. Electric Review*, 17,180 (1914).
[6]Abstract in *"Electrician"* (London), 69, 658 (1912).

It has been mentioned that the flame arc is of high efficiency. The following figures are from some regular routine tests made in the laboratory.

Lamp	Current	Kind of Carbon	M.S.C.P.	Arc Watts	Watts per Candle
Excello	A.C.	Cored—yellow	1220	363	.29—
Excello	A.C.	Cored—white	843	369	.43—
Excello	D.C.	Cored—yellow	1462	445	.30—
Excello	D.C.	Cored—white	875	450	.51—
G. E. Type W.	A.C.	Solid—yellow	700	397	.56—
G. E. Type W.	A.C.	Solid—white	808	394	.49—
G. E. Lynn..	D.C.	Solid—yellow	1181	409	.35—
G. E. Lynn..	D.C.	Solid—white	939	421	.45—

The slightly lower efficiencies with the solid carbons are due to the fact that they are used in enclosed lamps, to which the air has only limited access, and so in these lamps there is less oxidation of the carbon and the flame material.

Some work by Henry P. Gage[7] at Cornell University on the efficiency of the arc stream proper may be cited here. This investigator found that, with cored yellow-flame carbons the energy radiated as light from the arc stream was 39 per cent. of the total energy radiated by it; with the arc stream from cored white flame carbons 27.5 per cent. of the energy radiated by the arc stream was light energy. The entire yellow arc showed six candles per watt radiated, while the entire white arc showed three candles per watt actually radiated.

These values are for the spectral region between 3800 and 6800 Ongström units, and for alternating current at 13.5 amperes. The following data may be presented as to the life of flame carbons:

	Life in Hours. A. C.	D. C.
Cored, yellow.....	12.0	12.50
Cored, white.....	11.08	11.25
Solid, yellow.....	115.08	125.0
Solid, white	120.0	96.42

These figures show why the enclosed flame arc lamp is more popular than the old "inclined trim" lamp, using cored carbons.

Having indicated at a number of points the important part chemistry has played in the development of the modern flame carbon, let us now take up in greater detail some of the chemical aspects.

In the first place, the selection of the proper materials for the manufacture of flame carbons is to a very large degree dependent on the chemical properties of these materials. When we consider the carbon base, we find that the chemical behavior, as well as the physical behavior of the various so-called forms of carbon, differs with the type of carbon employed. To use an extreme case as an illustration, we know that the chemical properties of graphite differ greatly from those of lampblack. There are likewise similar differences between charcoal and lampblack; petroleum coke and retort coke. This, in part, accounts for a different carbon base being used for solid and for cored carbons.

To a greater degree than the proper selection of the right carbon base the selection of the right sort of flame material and the right sort of addition agents with this flame material has been a chemical problem. This is illustrated by the fact that to-day we know no better material than calcium fluoride for the main constituent of yellow flame carbons. I do not think I will exaggerate the matter in the least when I say that compounds of every compound-forming element have been proposed as proper substances to incorporate into flame carbons—some of them in all sorts of possible and impossible combinations.

Having selected the *right materials*, the right amount of each is our next chemical problem. That the candle power depends upon the amount of flame material is well known; more exact information on this subject, however, may be had from the following table, which is from some work done in our research laboratory by Mr. Wm. R. Mott, using cored carbons in an Excello direct current lamp:

Parts of calcium fluoride by weight	3	2	1	0
Parts of other salt by weight.....	0	1	2	3
Mean spherical candle power.....	927	1,058	765	574

As is seen, there is a maximum per cent. of each of the constituents which will give the most light. This is true with nearly every substance which may be added to the calcium fluoride, and when we consider that flamers contain three or more substances in addition to the main constituent, it is readily seen that the nice adjustment of all these substances to each other presents some very interesting problems. It also explains why so much of our knowledge has been obtained in an empirical way. It is, of course, understood that the maxima for different addition agents do not coincide.

The chemical control of the impurities present in the raw materials is of great importance. Silica, ferric oxide and alumina, as are well known, are common impurities in calcium fluoride, and it so happens that too much of these impurities will make a poor burning carbon. Silica is especially undesirable, as calcium silicate is very non-volatile and so is a frequent cause of slag formation. The analytical difficulties in determinations of fluorine, silica and rare earths in presence of each other and of carbon are very great.

The unbaked carbon is a poor conductor of electricity. It is also rather friable. In the baking, the binder is coked and the carbon is rendered homogeneous and conducting. This coking of the binder is the chief chemical change in the manufacture of the carbon.

We now have to consider what chemical changes may occur during the burning of a flame carbon, and how these may affect the light emitted from the flaming arc. There are three possible sources of light in the flaming arc: electro-luminescence, thermo-luminescence, and chemi-luminescence. We do not know to what extent these three factors affect the light radiation in any one case. We do know, however, that in general there are two types of flaming arcs, (1) those in which the outer sheath seems to be intensely luminous, (2) those in which the core of the arc seems to be more luminous than the sheath. With very few exceptions arcs of the latter type give light of the shorter wave lengths. We have here an arc into which calcium fluoride is introduced; it is a representative of the first type; here is an arc into which chromic oxide is introduced, it is of the latter type. King has recently reported[8] that in a tube furnace almost all of the spectral lines seen in the arc spectrum of titanium appear, so that it would appear that in some cases a large proportion of the light from an arc is due to thermo-luminescence, though all possibility of chemical change was not precluded by these experiments.

Oldenberg[9] has made a spectro-heliographic study of various arcs, with some interesting results: For instance, he concludes that in the sodium arc, lines belonging to the principal series such as the "D lines" are due to chemical reactions between the vapor and the air. Band spectra seem to be of two types: those of the first type are due to collisions of atoms, in the high temperature core of the arc. The cyanogen bands always seen in a carbon arc he ascribes to collisions between carbon and nitrogen atoms. Bands of the second type are found in the sheath of the arc; they are due to undecomposed molecules; the bands of the calcium fluoride spectrum are of this type. When we consider that the

[7] *Phys. Rev.* 33, 111 (1911).

[8] *Astrophysical Journal*, 39, 139 (1914).

[9] *Zeit. f. Wiss. Photog., Photophysik und Photo. Chem.*, 43, 133 (1913).

flaming arc is a miniature electric furnace; that Fremy[10] showed years ago that oxygen converts calcium fluoride into calcium oxide; that calcium oxide and carbon react to give calcium carbide and carbon monoxide, and that the other constituents of a flame carbon may react with calcium fluoride, with the carbon, with each other and the atmospheric gases, we see that it is possible for chemical changes to play an important part in the production of the light of the calcium fluoride arc. Each of the possible substances may play its part in this light emission.

In conclusion, I think we may safely say that the past progress made in the flaming arc art has been due to the co-operation of the chemist, the physicist, and the electrical engineer; the future progress will likewise be dependent upon their combined efforts.

It might not be out of place to point out that the behavior of any one substance in the arc is determined by the conditions surrounding that substance—it behaves according to definite chemical and physical laws, and that our knowledge of these laws for high temperatures is exceedingly meager. On the other hand, once these laws are learned, it will probably be easier to build lamps to suit the carbons rather than to make a carbon to fit any and every lamp. In the extension of our knowledge of these laws, chemistry and especially physical chemistry will play an important part.

The Quartz Mercury-Vapor Lamp

Mr. **R. D. Maily,** of the Cooper-Hewitt Electric Company, presented a paper on the quartz mercury-vapor lamp. After a description of the lamp, in which special mention was made of the ground seal of invar with mercury "lock," the author emphasized that the quartz lamp is a most convenient and inexpensive form of apparatus for the production of ultraviolet rays. He then discussed at some length the effects of ultraviolet rays, especially the sterilization of water, bromination of organic compounds, photographic plate reactions, linseed oil clarification, etc., and made numerous demonstrations. The evolution of the quartz lamp has also been a development in the manufacture of clear transparent quartz apparatus.

Gaseous Electric Illumination

Mr. **D. McFarlan Moore,** of the Edison Lamp Works of the General Electric Company, Harrison, N. J., presented a paper on "Electrochemistry and the Development of Vacuum Tubes, and the Moore Light."

The author gave an interesting account of his early pioneer work begun in 1894 on "filamentless lamps." He described how in his early experiments with vacuum tubes the illumination depended on the kind of alcohol used in cleaning the tubes, how the long-tube system was worked out, how both external electrodes and internal electrodes were tried. Many experiments were made on feeding a gas to a tube or generating the gas in the tube itself. In 1896 the feed valve was perfected and experiments were made with various gases. Most interesting from a commercial standpoint was nitrogen, because it produced the most light with the least electric power consumption. Later color matching outfits were worked out, and so on.

But an immense amount of research work remains still to be done, especially along two lines. First, as to the most suitable electrodes, and second, as to the properties of the individual gases. For each individual gas there is a most suitable electrode material. Among the gases neon has become most interesting in recent times. The author concluded with a sketch of various theories on gaseous conduction and luminescent lighting.

[10] *Ann. Chim. Phys.* (3), 47, 17 (1856).

The Use of Hydrometallurgical Apparatus in Chemical Engineering*

BY JOHN V. N. DORR

This paper, although the title is somewhat general, will be devoted principally to a description of the apparatus with which my name is connected. It was prepared at the suggestion of President Whitaker who felt that it would interest chemical engineers to know of methods which have proved of definite value in metallurgical work where large quantities of material are handled with low costs.

Metallurgical engineering is really one department of chemical engineering in its broadest sense.

General Metallurgical Tendencies

Comparing metallurgical operations of to-day with the work of thirty years ago, we note that nearly everything is done on a much larger scale.

One reason for this is the general development of engineering knowledge with improved materials and the substitution of exact scientific methods for the old "rule of thumb" ways.

Another is the greatly increased demand for metallurgical products, the consumption of all the common metals having increased several times as fast as the growth of our population.

A third and perhaps most important reason is that most of the smaller rich ore deposits have been worked out so that we have been forced to attack the large low-grade deposits which twenty years ago were considered of no value.

This tendency is well shown by the treatment of the disseminated porphyry copper ores and the handling on a much larger scale of the lower-grade ores at Butte and in the Lake Superior district.

The introduction of mechanical power in place of hand labor has, of course, been as important a factor in metallurgical progress as in all other lines of endeavor.

The introduction of continuous methods in the different steps of metallurgical processes in place of intermittent methods formerly used has meant great advances.

Continuous work means invariable lower labor costs and a high load factor, thus assisting in lower power costs and interest charges. Where the change does not sacrifice control of the operation it results usually in allowing a large output of uniform nature.

As illustrations of this tendency towards continuous work in metallurgy may be noted the use of pan conveyors and rotary cylinder feeders in delivering ore to primary crushers, automatic weighing machines and belt conveyors for the transport of dry material around a mill. The belt conveyor is also in use in stacking tailings from leaching tanks and has been used to stack slime tails from an Oliver filter and dewatered sand tails from a Dorr classifier.

In smelting plants we see the use of mechanical roasters and sintering machines, such as the Dwight-Lloyd, with continuous removal of slag by granulation.

The change in cyanide practice has been quite marked. Where leaching was practiced the original means of removing slime was to collect the sand in tanks while overflowing the slime and then shovel or otherwise transfer the sand so collected to other vats for leaching.

Continuous separation, whether by cone or mechanical classifiers, has done away with this, and the sand

*A paper read at the Philadelphia meeting of the American Institute of Chemical Engineers on December 4, 1914.

usually passes directly to leaching tanks without coming to rest.

In slime treatment, whether of classified slime or the whole mill feed reground, Dorr continuous thickeners have made continuous settling feasible, and continuous agitation has replaced the charge system for the dissolution of precious metals, with a very definite saving in power, attention and first cost of the installation required. The Oliver continuous filter has come into extensive use for that step in the process, and it is interesting to note that the decantation process, the first method used for the recovery of dissolved gold from slimes, which was abandoned everywhere except in South Africa on the introduction of the modern type of filter when made continuous by the use of the Dorr thickener, is coming into extensive use again and displacing in some instances an intermittent type of filter.

Zinc dust precipitation when first introduced as an intermittent process could make no headway against continuous precipitation with zinc shavings, but since being made a continuous process by Merrill has come into extensive use in modern mills.

Interchange of Apparatus in Industries

One characteristic of technological work in the last few years that was not in evidence in the centuries preceding is the exchange of information among workers in different fields.

Although the total knowledge in the world has increased so enormously, and this has been called very properly an age of specialization, the specialist is expected to have a general knowledge of progress outside his own field to such an extent that he can profit by it in advancing his own work.

This has been made easier in metallurgy more than in chemical engineering, I should say, by the greater freedom among metallurgists in the exchange of data. A valid reason for this is that the metallurgist competes in a much greater degree with natural conditions than with other producers of the same product.

The price of gold is essentially constant whether more or fewer mines are operating and, while the prices of silver and the base metals vary with the supply and demand, the profits made depend so greatly on other factors, such as richness of the ore and costs of mining and milling, that I doubt if any producer would hope to get an advantage over the others by secrecy. In fact, there is a general understanding among the larger copper companies to-day for an exchange of information which gives them all an advantage in the combat with Dame Nature.

In manufacturing, on the other hand, there is theoretically competition for the purchase of the raw material and the sale of the finished product so that manufacturing costs and profits must come between the two, and any advance that can be made in reducing the former unless kept from competitors seems of no real benefit.

The cyanide process has been benefited by the adoption of methods and machinery from other industries and has made its own contributions in return for benefits received. Fine grinding has been aided materially by the adoption of the tube mill from cement grinding, and when dry crushing and chlorination on Cripple Creek ores was in vogue the inclined traveling screens used in clay working were of great assistance as were the dust collectors taken from Minneapolis flour mills.

Our early paddle arm agitators came from chemical works and the air-lift agitator, or "Pachuca" tank which succeeded them, was first used, I am told, in a powder plant in California.

The Dehne filter press, so extensively used in Australia, was another adoption from chemical industries, and the rotary drum filter was used in Syracuse as a dewaterer of chemical precipitates before the cyanide process was known.

As developed by Oliver, with means for washing and blowing off the cake formed, it has been returned by the cyanide operator to several industrial uses.

Various forms of vacuum and pressure "cake" filters, such as the Moore, Butters, Kelly and Sweetland, might be said to have their prototype in the potter's method of making pitchers. This is done by pouring "slip" into a plaster of Paris mould and when a solid deposit has been formed by the absorption of moisture pouring out the remainder of the liquid "slip" and drying the vessel thus formed in the mould. From cyaniding they have found their way extensively into sugar refining, alkali work and many other lines. The Merrill sluicing press is being installed in a large aluminium plant in the South.

In closing this general discussion I will say that, while the basic principles for the mechanical treatment of analogous materials are the same, great caution should be used in proposing the substitution of any method or apparatus successful in some other field for that now used. It is safe to assume that the latter is in use as a result of much study and gradual development, and its replacement should be preceded by a most careful detailed study of all the conditions of operation and purposes to be accomplished.

Suggestions as to such substitutions may be advanced tentatively, but an actual demonstration is worth a lot of theorizing. In introducing new methods we usually find troubles come where not expected, and apparent difficulties do not prove real.

The Dorr Apparatus—General

The apparatus which I wish to call to your attention was developed by me in the last ten years in the course of operating cyanide mills in the West. Each machine performs a certain useful function satisfactorily and economically, and I feel that you will agree with me that where similar work is to be done they are worthy of consideration. I do not mean, of course, that a machine adapted for handling a sandy pulp is necessarily the best type to handle an extremely light chemical precipitate, but I feel that where the operations of washing, settling or agitation are required they may be of service.

As a generalization, I believe I am safe in saying that machinery successful in operations where costs per *ton* are studied to a fraction of a cent, have possibilities where materials are handled on which costs per *pound* are watched. It is true, on the other hand, that the economies of continuous work decrease with a reduction in tonnage, so that each case has to be studied by itself. In discussing the apparatus I have of necessity quoted freely from my paper on the same read at the Salt Lake meeting of American Institute of Mining Engineers in August, 1914.

The Dorr Classifier

This machine was devised by me in 1904 to replace hydraulic cones for the purpose of making a separation of sand and slime at the mill of Lundberg, Dorr & Wilson at Terry, South Dakota. The method of cyaniding the gold ore in use at that mill was crushing to pass a 20-mesh screen, separating the sand from the slime, leaching the sand in vats by percolation and treating the slime after agitation and thickening by the Moore filter process. The machine proved such an improvement over the cones in use at our plant and elsewhere that it was rapidly adopted and has come into wide use.

It has been improved from time to time to meet new

conditions and as now manufactured is shown in Fig. 1, which illustrates the standard duplex machine.

The Dorr classifier consists of a settling box in the form of an inclined trough with the upper end open, in which are placed mechanically operated rakes or scrapers for the purpose of removing the quick-settling material from the open end, the liquid and slime overflowing at the closed end. Each rake is carried by two hangers, one at the sand-discharge end suspended from

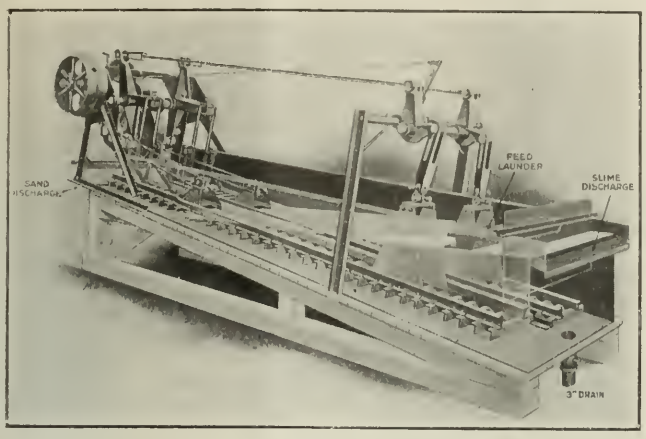


FIG. 1—THE DORR CLASSIFIER

an arm attachment to a rocker arm or lever which terminates in a roller. The other suspends from a bell crank connected by a rod to the same rocker. The roller is kept pressed against a cam on the crankshaft by the weight of the rakes.

The rakes are lifted and lowered at opposite ends of the stroke by the action of the cams transmitted through the rocker arms and bell cranks, and the horizontal motion is obtained directly from the crank.

The bell cranks at the slime end are carried by a second larger bell crank held in position by a chain attached to a spool on a worm gear at the head end of the classifier. By this means the rakes can be raised 10 in. at the lower end and operated in that position or any intermediate one. This allows the classifier to be started readily when nearly filled with sand after an unexpected shutdown, and the regulation of the depth of the settling box when in operation to vary the products being made.

The pulp is fed across the settling box as shown and a uniform flow to the lip at the end is maintained, while the sand settles to the bottom and is advanced by the rakes until it emerges from the liquid and is discharged with from 20 to 30 per cent moisture.

The agitation near the bottom of the tank caused by the reciprocating motion of the rakes assist in keeping the slime in suspension, but is not normally sufficient to cause fine sand to overflow.

REGULATION OF PRODUCTS

The machine is intended, of course, to make only two products, and the point of separation can be varied by the following means:

1. The use of the baffle shown, which allows a reduction of the cross-section of flow so as to overflow more fine sand.
2. Raising the rakes and thus obtaining the effect of operating them in a shallower tank.
3. Increasing the speed of the rakes until the agitation keeps fine sand in suspension.
4. The attachment of perforated spray pipes to the rakes at a point where they remove the sand from the liquid, allowing a rewashing of the sand and removal of any slime that may be carried down with it.

This latter feature will probably be of more interest from the chemical engineer's standpoint as enabling him to discharge finely divided sandy material and give it a complete wash to free it from any dissolved material which adheres to it.

CAPACITY

The capacity of the Dorr classifier depends upon the dilution of the feed and the point of separation which it is desired to make. The rakes of the Simplex machine, operating at normal speed, are able to discharge at least 150 tons of solids in 24 hours.

Table I, showing results at different plants, will give the best idea of what may be expected.

COST OF OPERATION

Experience has shown that repair costs on these machines are extremely small. I know of one classifier which operated nearly four years with repair costs of less than $5, and a half a mill per ton seems a safe figure. While the power taken will vary of course with the load, it appears that ¼ horsepower is ample in most cases. With normal feed the attendance required is practically nothing, being limited only to an occasional oiling. All parts in reciprocal motion are removed from contact with the liquid, so that there is no opportunity for wear starting at any point.

TABLE I—OPERATING DATA ON DORR CLASSIFIERS

Mill	Tons per 24 Hr.	Feed			Sand			Slime		
		Dilution	+100	+ 200	—200	+100	+200	—200	+100	+200	—200
Portland, Colorado	145[a]	5 to 1	38.3	13.4	47.1	75.3	16.2	7.4	0.9	5.8	94.7
Golden Cycle, Colorado	151[a]	3.5 to 1	45.0	19.0	36.0	68.0	23.0	9.0	...	11.0	89.0
Cia Benef. de Pachuca, Mexico	144[b]	4 to 1	42.7	25.1	32.5	43.6	40.1	16.8	0.1	3.8	96.8
Tonopah Extension, Nevada	73[c]	6 to 1	65.0	11.1	23.9	70.0	18.3	11.7	0.6	8.5	90.9
Amparo Mining Co., Mexico	125[a]	7.5 to 1	52.4	18.5	29.1	71.4	27.4	1.2	...	6.5	93.5
Tonopah-Liberty, Nevada	85[c]	7 to 1	30.5	41.9	26.3	75.7	24.0	0.1	2.5	14.3	81.4
Goldfield Consolidated, Nevada	264[d b]	3 to 1	40.0	12.0	48.0	74.0	19.0	7.0	2.6	19.5	79.1
Tonopah-Belmont, Nevada	70[e]	.....	65.6	2.7	28.9	....	....	....	0.4	6.6	93.0
Alaska-Treadwell, Alaska[e]	89[e]	.....	48.7	41.5	9.8	48.7	41.5	9.8	...	2.0[e]	98.0
Nipissing, Canada	...	.....	78.7	3.6	16.8	85.8	7.2	6.9	...	0.5	99.5[f]

[a] New ore.
[b] Includes tube-mill return. Under normal conditions, with a tube mill in closed circuit with a Dorr classifier, 35 to 50 per cent. of original feed returned.
[c] New ore; tube-mill product returned, but amount not stated.
[d] 168 tons come from the stamps, the rest being returned from the tube mill.
[e] Classifiers used in connection with the regrinding of concentrator; rakes operated 24 strokes per minute; 100 per cent. of concentrates pass 200 mesh; the 2 per cent. is silica from tube-mill pebbles.
[f] Of this 200 mesh product 15 to 20 per cent. is sand; crushing is done in two sets of tube mills; the sand from the first classifiers being reground in closed circuit with the tube mills and other classifiers, the combined slime overflows giving the screen test shown.

USES

Besides being used to separate a leachable sand product from slime, Dorr classifiers are in general use to-day in connection with fine grinding.

Fig. 2 shows the arrangement of Dorr classifiers and tube mills operating in closed circuit in the Tonopah-Belmont mill. It is considered much more economical in power and equipment when a product 150 mesh or finer is desired, to pass a large tonnage continually through a tube mill, return the discharge to a Dorr classifier and overflow the part which is ground fine enough, returning the balance to the same machines for further grinding, together with the sand coming

from the new feed. This is considered much more efficient than to attempt to reduce the product to the size required in one passage through the tube mill. It seems more than probable that it will prove equally advantageous in connection with industrial pulverization of quartz, cement material and other mineral products that require fine grinding. Some work has already been done on thes lines, especially in connection with pigment grinding, but I have no data that are at present available.

Dorr classifiers are now in successful use as dewaterers of concentrates, both magnetic iron concentrates and sulphides, and are discharging the former at one plant with only 12 per cent. moisture.

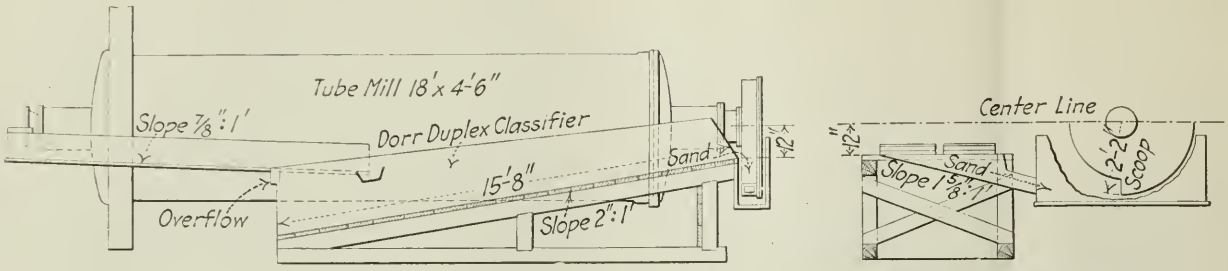


FIG. 2—ARRANGEMENT OF DORR CLASSIFIERS AND TUBE MILLS OPERATING IN CLOSED CIRCUIT IN THE TONOPAH-BELMONT MILL

LEACHING

The use of a series of Dorr classifiers for the purpose of leaching and washing was first suggested by Mr. Utley Wedge, and some experiments were made along that line several years ago but not carried to a conclusion. Last year Captain Wolvin of the Butte-Duluth Company at Butte, who was leaching oxidized copper ores in vats there, brought up the same idea and we furnished him with five classifiers for trial, with all parts, subject to contact with the acid, made of hard wood. These machines proved very successful, increasing the extraction over the former leaching in vats at least 20 per cent. and we have since then furnished them with more machines for the same purpose. Fig. 3 shows the discharge of tailing from the last machine of a series.

I have been unable to get reliable detailed results of these operations, as they have been changing details from time to time, but the following data obtained last summer from the Butte-Duluth Company, when the first installation, consisting of six small classifiers, was in use, will give an idea of the operations at that time.

6 Classifiers in series, 5-15′ x 4½′, 1-30′ x 4½′.
Ore crushed through .12″ opening in inclined impact screens, giving a product of about —10 mesh.

Value of heads	2.14% Cu.
Average strength, H_2O_4 acid used	7.33%
Ratio of solution to ore	2.25 to 1
Moisture in discharged tails	20%
Extraction	89.9%
Value of solution going to cells	1.8% Cu.
Value of solution from cells	9% Cu.
Speed of Classifier rakes, strokes per min	6
H.P. (motor 86% efficient)	4.6

The average daily capacity for the month in which the above figures were obtained was about 150 tons. The limit to the capacity was the lack of electrolytic cell room.

Spent electrolyte after strengthening was added to the first two classifiers and water into No. 6. Most of the overflow from the latter went to scrap iron precipitation and an amount equal to the acid liquor brought out from No. 5 with the ore was carried through Nos. 5 and 4 to No. 3, thus effecting a countercurrent washing. The overflows from Nos. 1, 2 and 3 after clarifying were sent to electrolytic precipitation. The ore received about 40 minutes' contact while passing through the whole series.

TRIPLE-WASHING CLASSIFIER

Fig. 4 shows a machine which we have designed to wash a sandy material absolutely free from any trace of slime or to wash the same kind of material entirely free from any liquid in which it may be suspended. It will be noted that there are a number of opportunities to get rid of the liquid or slime mentioned.

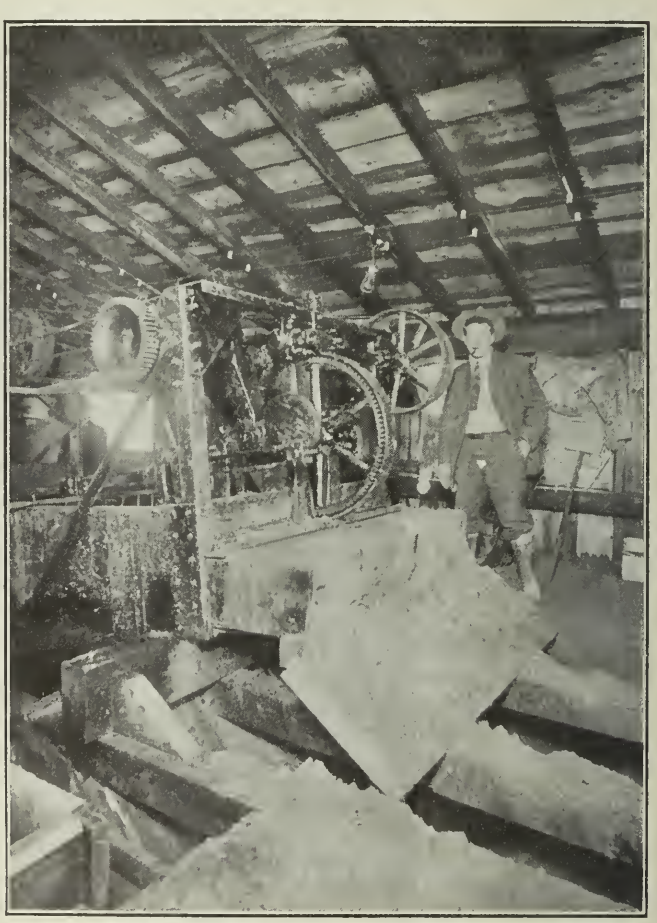


FIG. 3—TAILING DISCHARGE BUTTE-DULUTH COPPER LEACHING PLANT

First, as the sand is raked up above the water level in each box it is sprayed with any solution or water. Second, as it is washed into the following box it is diluted with the same liquid, so that in all it gets a very thorough treatment.

POSSIBLE USES OF THE CLASSIFIER

Several Dorr classifiers are now in operation at one of the mid-Western chemical works, used, I believe, for draining a granular chemical precipitate and washing same. Its use in connection with clay-washing in the preparation of a high-grade kaolin, in place of the settling boxes which now require a great deal of labor for removing the sand from them, is now being considered and its use for dewatering or removing granular material from any liquid will be apparent.

(To be concluded in the February issue.)

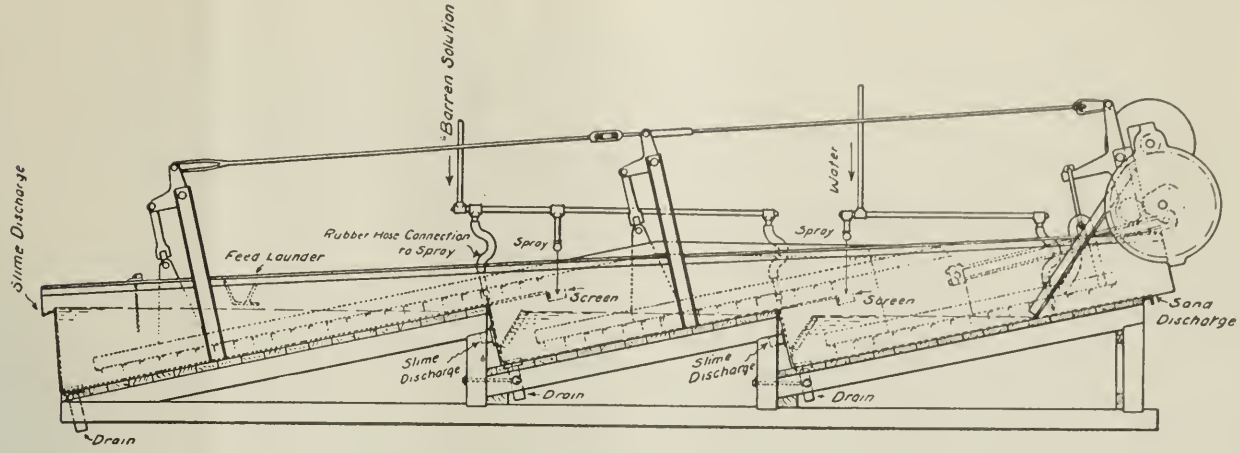


FIG. 4—THE TRIPLE-WASHING DORR CLASSIFIER

The Chemical Trade Situation in Germany and Great Britain

(From the London *Engineering*, December 4, 1914.)

The much-discussed subject of the control by Germany of a large portion of the chemical industries came before the Society of Arts [in London] on the two last Wednesdays in connection with two papers read respectively by Sir William Tilden and by Mr. W. R. Ormandy, D.Sc. Neither speaker took what we may briefly designate as the commercial point of view, nor did either enter into details of technical problems; Sir William Tilden gave a few statistics, Dr. Ormandy none at all. Both accentuated the general development of industry on methodical scientific lines, and as Dr. Ormandy adopted the more general and broader standpoint, we will begin with his lecture of last Wednesday.

Lord Moulton, the chairman, opened the proceedings by a few words, which made a deep impression. Speaking under visible emotion, and in terms which would have commanded the respectful assent of men of any nationality, he said that he had had to investigate the question of the supply of certain chemicals formerly obtained from Germany, and the facts were a cause for sadness and national humiliation. The chemical industry, except those branches which required least knowledge, thought, and least study, had, for reasons, perhaps, of our manufacturers being too well off, or of sluggish intellect, been allowed to fall into other hands. It was not that England was incapable or unfitted for the industry. They had to look for some fault in their national character or in their national behavoir, and they had to learn from the enemy. The most glorious moment in Prussia's history had not been their military success, but the period of deepest distress following 1806, when men like Fichte had not spared them, but had told them that only self-discipline and recognition of their national faults could help them to regain their self-consciousness and honorable position. Our position was not that of Prussia after Jena, but it was grave enough. Something more than contemplation of immediate profit was required; we had to rouse ourselves to save ourselves from German industrial domination, as well as from her military domination.

In commencing his remarks, Dr. Ormandy pointed out that when the introduction of the steam engine as a means of power and transport had rendered industrial development on a large scale possible, Europe outside the United Kingdom was in an unsettled condition, and this country could thus become the workshop of the world. British manufacturers paid low wages for long hours, and made enormous profits. Orders for steel and tools were given without much inquiry about prices, provided quick delivery could be guaranteed. The subsequent rapid development of foreign countries demanded capital for railways, shipping, mining, etc., and the best returns could be obtained from such ventures. English spinners and weavers were supplying the world with their products, while loom and mule machinery makers worked night and day to supply the infant foreign industries with the machinery necessary to compete with England in markets in which this country had held a monopoly.

The commercial life of Germany might be said to have commenced little more than a generation ago. An inland country, with little seaboard, few raw materials, no iron ores comparable to Cumberland hematites, and rather poor coal in distorted seams, Germany had seemed at a huge disadvantage. It was early recognized, however, that progress could not be left to individualistic effort. Too much credit could not be given to the far-sighted way in which problems of agriculture and industry were in Germany regarded from a national standpoint, while in this country [Great Britain] individualism was running rampant. The very people whose fathers had sold land to the railway companies at absurdly inflated prices now complained that, owing to the high freights, they could not make adequate profits from the investment of the money obtained from the same railway companies by an earlier extortion. In Germany afforestation was compulsory; enormous areas, fit for little more than potato cultivation, enabled Germany to produce glucose, starch and alcohol for all Europe. The iron exports, twenty years ago also insignificant, now exceeded the British exports by nearly 100 per cent. Realizing that all industrial progress was becoming more and more scientific, and that the adequate utilization of the by-products might settle the survival of the industry itself, by-product recovery coke-ovens, which also supplied the raw material for dyes previously obtained from England, were installed in the imme-

diate neighborhood of the blast-furnaces, and the surplus gas from both was utilized for power generation. Favored by Nature to an extraordinary degree as to pottery, English workmen had acquired a wonderful skill for the production of objects of art; but when the demand arose for complex porcelain castings of high-insulating capacity, Germany was able to secure that market.

The lecturer then passed to other features. Some one said that a nation got the newspapers it deserved. Judging by what had recently appeared in some portion of the [British] daily press upon German trade, it was devoutly to be hoped that the common-sense of the British nation would not be judged thereby. During the past ten years more than sixty millions of Germans had been fully occupied in industrial operations; our own [Great Britain's] population had equally fully been occupied, and yet people wrote as though there were a possibility that a large proportion of the activities of the larger nations could profitably be undertaken in a smaller country whose own workpeople had for the most part been quite busy.

Passing to the German willingness and ability to work in co-operation and to the great help afforded by banks to industry, Dr. Ormandy said that the heads of German banks were men of high technical knowledge, and not stockbrokers or retired colonels. These men were accessible to the inventor and ready to avail themselves of technical experts of the highest class to investigate new processes.

The other lecture upon "The Supply of Chemicals to Britain and Her Dependencies," which Sir William Tilden, D.Sc., F.R.S., delivered at the Society of Arts on Wednesday, the 25th ult., was more a plea for scientific research than a commercial review or a statistical compilation. "There is only one road to permanent industrial success, and that is the way pointed by science," was Sir William's advice to the chemical manufacturer. It was the old story in a new garb: chemical industry—some branches of it, at least—had migrated from this country [Great Britain], its original home, to Germany, and the country was now, the speaker said, in want of products which it ought to produce itself.

In his introduction, Sir William Tilden pointed out that Germany had contributed little to laying the foundations of theoretical chemistry a century ago. There had been no German chemist of the first rank, and only one fundamental German discovery, the discovery of isomorphism by Mitscherlich in 1819. Liebig, born in 1803, was the first of the great German chemists. If Professor Tilden had gone three years further back, to the beginning of the century in 1800, he would not have overlooked the birth of Friedrich Wöhler, a man whom chemists are justified in revering as one of the first men of his century and as the father of synthetic organic chemistry, in which, Sir William afterward remarked, "the most remarkable successes have been won, though not wholly, as sometimes represented, by the German chemist."

Turning to the position of industrial chemistry, Professor Tilden quoted the report on chemical processes and pharmaceutical products and processes at the second International Exhibition of 1862, by August Wilhelm Hofmann, then Professor of Chemistry at the Royal College of Chemistry and Mines: "The contributions of the United Kingdom have not only maintained their preeminence, but outdone their own admitted superiority on the corresponding occasion of 1851." Of 762 exhibitors in the class, 200 belonged to the United Kingdom, 136 to the Zollverein and 115 to France. The statistics of Allhusen and of Gossage showed that the production of heavy chemicals (alkalis, acids, manures, etc.) had nearly doubled between 1852 and 1862. Recent Board of Trade statistics proved that in these respects British manufacturers had no need to fear German competition in the home market.

But it was different in coal-tar dyes, drugs, antiseptics, essential oils, aromatic substances, materials for photography, pure chemical reagents, and the many other indispensable products of modern chemistry. The sources of supply of all these materials in the United Kingdom was seriously inadequate. In alizarin, anthracene, aniline, etc., dyes this country imported from Germany, in 1913, goods totaling £1,653,600 in value, and, further, £76,681 worth of synthetic indigo. Drugs, including medicinal preparations, were imported in the same year to the amount of £1,302,860, and more than one-fourth of these came from Germany, to which only £24,690 worth of coal-tar products were exported. No figures were available as to fine chemicals for analysis, but he might safely say that there was no appreciable production of these things in Great Britain. If that statement were to be met by protests from manufacturers, it was only necessary to refer to the experience of analysts and directors of research laboratories, who had habitually to resort to German makers for their supply of trustworthy reagents.

A chemical manufacturer, discussing the neglect of fine chemicals in this country, had recently remarked, "What does it matter if we are making money?" "I venture to say that that view expresses neither patriotism nor common sense," was Sir William's comment. German chemists were, indeed, attacking the market for heavy chemicals already. They, Sir William continued, exported three times as much sulphuric acid in 1912 as the United Kingdom did in 1913, and they arrogated the whole field of scientific and industrial chemistry to themselves.

In support of this statement, Sir William mentioned that Emil Fischer, in delivering the inauguration address of the Kaiser Wilhelm Gesellschaft zur Förderung der Wissenschaften, had suppressed every foreign name except that of Perkin. That is not quite correct; Sir William was rather severe, and he might, we venture to suggest, have clothed his allusion to that institution in such words as to further his own object—the promotion of scientific research. The facts are that large sums of money had been collected for the advancement of science; German chemical industry, though prosperous, wanted her institution for chemical investigation; the scheme became more and more ambitious, as money poured in, and to make further propaganda Emil Fischer traced in his address the relationship between science and chemical industry in Germany. It was a *pro domo* speech, not rich in names; there was no particular reason for introducing foreign names; yet, we grant, Fischer should not have confined himself to Kelvin, Perkin, Dewar, Berthelot and Baekeland.

In recalling the circumstances which had led to the gradual transference of the color industry from England to Germany, and to the failure to establish here any appreciable production of synthetic drugs and chemicals, Sir William Tilden regretted that A. W. Hofmann was allowed to return to Germany, where a Chemical Society was only founded in 1867, while the Chemical Society of London dates from 1841, and he blamed the antiscientific spirit and the neglect (up to 1885, at any rate, when Sir William Perkin commented upon it) of research by the old universities of this country [England].

That had quite been altered since then; yet it was necessary to insist that no man should be appointed a professor of natural science who had not shown his ability by original research, and the professor should have a sufficient staff of properly-trained assistants to

enable him to pursue a promising line of investigation. Forty years ago British chemical works had no qualified scientific chemists; in the palmy days of color-making hardly any British manufacturers probably had ever heard of Kekulé's benzine-ring theory, to which German chemists primarily ascribed their prosperity. German indigo had almost driven the Indian planter from the field; the value of natural indigo from India imported into this country [Great Britain] had fallen from £124,-112 in 1909 to £48,208 in 1913, while £76,861 worth of synthetic indigo had been imported from Germany in 1913, as mentioned above. "The strength of our competitors is in their laboratories, and not, as here, on the Exchanges," Professor Meldola had said. The maxim which we quoted in our first lines was indirectly suggested to Sir William by a lecture, delivered by H. Brunck, on "The History of the Development of Indigo," at the Hofmann House in Berlin in 1900, which lecture, Sir William said, "might be regarded as a sermon preached to British manufacturers."

In order to render the Empire independent of supplies from foreign sources, Sir William stated the industry wanted many first-rate chemists, a few engineers, plenty of capital, and some good men of business. It was right to learn from the enemy. British universities could supply the chemists if manufacturers would treat them more reasonably and liberally. The German large works took young university men on the recommendtion of the professors, placed them under the chief chemist of the department in the research laboratory, and paid them a salary sufficient to live modestly; their future depended upon their ability. The engineer was, of course, indispensable. As regards buildings, structures, supplies of water, fuel, power, and electricity, the engineer had the field to himself; but the chemist ought to be supreme as to chemical operations, and in the dye manufacture, *e.g.*, the chemist at present required little assistance from the engineer. We should submit, however, that in the practical adaptation of a process success will much depend upon the engineer. It has been acknowledged that Knietsch finally was able to make the contact sulphuric acid process a success because he was a first-class engineer as well as a chemist.

Sir William, in concluding, said that the establishment of what would practically be a new industry (after the war) would require State aid, and that aid had been promised to the dye industry; it would have to be extended to those chemical products on which the dye manufacturer depended.

In inviting discussion of the paper, Sir William Ramsay, the Chairman, in strange contrast to Lord Moulton, said that the Germans organized a chemical trade campaign as they organized a war. Expert committees looked out for new markets and raw materials, created a demand for them, had agencies all over the world, advised as to loop-holes in patents, and framed the patent laws so as to exclude the foreigner, all this with State aid bounties, export duties, &c. Some British works were, of course, quite as splendidly equipped as German works; but the small manufacturers had to be protected by organization, lest they cut one another's throats.

Professor James J. Dobbie, of the Government Laboratory, agreed with the lecturer, and referred to one point, the unreadiness of the British chemical manufacturer.

Professor A. G. Green, of Leeds, said that the question was simply one of knowledge; the Germans considered it worth while to pay for it, over here we did not. He would give a characteristic case. A firm wishing to take up a new explosive advertised, not for a chemist, but for a workman acquainted with the process; they got one formerly with a rival firm; he wanted fuming sulphuric acid, and the firm again advertised for a workman.

Dr. Chapman pointed out that in the science of brewing England was certainly in the forefront, to which the lecturer readily assented; he had deliberately omitted reference to brewing.

Mr. Walter Reid complained that the British inventor had to go abroad to get his invention worked. He had made the first smokeless powder, and offered it to the government, but his offer had been declined because they would have had to change their rifles. The British manufacturers were an untrained mob against an organized army. He had his doubt about government factories; the Board of Trade should really do something for trade, and be an advisory body; success of the National Physical Laboratory was largely due to the guidance it received from the general board, on which practical men had seats.

Mr. C. E. Cassal, of London, stated that if chemists were advertised for at £65 [or $325] annually, and Honors men were offered a final maximum of £150 or £200 [or $750 to $1000] as chief chemists, nobody could expect able men to select the chemical profession.

Sir William Tilden, in his final brief reply, repeated that the German works did not offer their staff more. Those men came direct from the universities, and had to learn their business first; no college could teach industrial chemistry.

Synopsis of Recent Chemical and Metallurgical Literature.

Gold and Silver

Precipitation of Gold from Solution—A method for the exact precipitation of gold from a solution, for example, after it has been separated from silver and platinum group metals, is given in the September, 1914, *Journal* of the Chem., Met. & Min. Soc. of S. Africa, by Mr. H. R. JOLLY. The solution of gold in aqua regia is "neutralized with a 20 per cent caustic soda solution. The beaker is then put on a hot plate, the contents warmed gently, and about 5 to 8 cc of a warm 10 per cent solution of potassium cyanide added, and the solution allowed to stand for about ten minutes. Thirty cc sodium sulphite 20 per cent solution are then added, and the beaker allowed to stand for about ten to fifteen minutes longer on the hot plate, after which it is removed and the contents diluted to about 300 cc. The process to follow is the same as the precipitation of a cyanide solution by Mr. Whitby's method. The reagents are added to the solution in the following order and quantity: 8 to 10 drops of 10 per cent potassium ferrocyanide, 30 cc of 20 per cent copper sulphate, 30 cc 20 per cent sulphuric acid, and 10 cc sodium sulphite. It is absolutely necessary to stir the solution after the addition of each reagent. The precipitate is allowed to settle and collected on a filter paper; after draining, the filter paper and its contents are put into a No. 1 assay pot, fluxed and fused in the ordinary manner. The lead button obtained is cupelled, the bullion bead parted and the gold weighed.

"Check gold was dissolved up in dilute aqua regia and treated as above. The following table shows the results:

Original Weight. ½ mgm.	Weight after Treatment. ½ mgm.	Loss ½ mgm.	Percentage Extraction.
24.54	24.50	0.04	99.83
34.74	34.73	0.01	99.97
30.44	30.44	...	100.00
10.22	10.20	0.02	99.80
26.45	26.40	0.05	99.81

"According to Watts' *Dictionary of Chemistry*, potassium auricyanide is formed by adding neutral gold chloride solution to a hot concentrated solution of potas-

sium cyanide, and it is on this reaction that the foregoing method is based. It is, however, necessary to reduce the gold to the aurous state in order to get complete precipitation, and this is accomplished by adding sodium sulphite."

Chemical Engineering

Removal of Sulphurous Acid from Fumes.—In an editorial on progress in fume recovery in our November issue (page 670) reference was made to a German invention for the elimination of sulphur dioxide from furnace gases by means of dicalcium phosphate. As several inquiries have been made concerning this process, we give here some details from the patent specification, although the patent is not of recent date (German patent 160940, class 12*i*, granted on May 26, 1905). The inventors are Eugen Bergmann and Theodor Berliner. If dicalcium phosphate is used as absorbent in presence of water, the sulphur dioxide decomposes the dicalcium phosphate according to the equation

$$2\ Ca\ H\ PO_4 + 2\ SO_2 + 2\ H_2O = Ca\ H_4\ (PO_4)_2 + Ca\ (HSO_3)_2.$$

This reaction occurs at ordinary low temperatures, and by this reaction it is possible to absorb the sulphur dioxide even from fumes in which it exists in great dilution. By a simple moderate elevation of the temperature to not more than 100 deg. C. it is then later possible to regenerate the dicalcium phosphate and recover the sulphur dioxide, since at the higher temperature the above reaction proceeds in the opposite direction (from the right to the left of the equation). The process is, therefore, cyclic with respect to dicalcium phosphate which alternately absorbs and gives off sulphur dioxide.

Lead Acetate Test for Hydrogen Sulphide in Gas.—The effect of the following factors upon results obtained in tests for the detection of hydrogen sulphide in gas by the lead acetate test has been investigated by the Bureau of Standards, Department of Commerce, and will be published in the forthcoming Technologic Paper No. 41 of that bureau: (1) The paper, kind, method of preparation, including the strength of lead acetate solution used, and the moisture content when used. (2) The gas, its humidity, and the period and rate of flow. (3) The apparatus, its form and size, as determining the circulation of gas with respect to the paper. With gas mixtures containing various known amounts of hydrogen sulphide these several factors were studied one at a time and the following conclusions reached: (1) An operator, by giving consideration to the desirable qualities which are pointed out, can easily select the most suitable and convenient kind of paper after a trial of a number of samples; the convenience, but generally not the accuracy, of the test is affected by the choice. There is little or no difference in the sensitiveness of the paper prepared with lead acetate solution from 2 to 12 per cent in strength; a 5 per cent solution is recommended. Treatment of the papers with ammonia or carbon dioxide does not materially change their sensitiveness. It is recommended that the test paper be dipped in lead acetate solution, blotted, and used moist, since such paper gives the most reliable results. (2) The large effect of the humidity of the gas upon the test results is shown; but it is also noted that the use of moist paper with short test periods (not over three minlutes) gives results practically independent of the humidity of the gas. It is impracticable either to dry or to saturate the gas to a constant condition as to humidity, because of the probability of simultaneous change in the hydrogen sulphide content. (3) The rate of gas flow has some effect, but increases in rate produce less effect than proportional increases in the time of test. The general practice of making tests at 5 cu. ft. per hour is satisfactory; maintenance of the rate within the limits 4.5 and 5.5 cu. ft. per hour is sufficient. The time of test is an important factor in determining its sensitivity; the proper basis for selection of the length of test is treated in connection with the discussion of the quantitative and engineering significance of the tests.

The different forms of testing apparatus used may be classified into three groups, circulating, impinging, and penetration, these being distinguished by the manner in which the gas is brought into contact with the paper. The five forms of circulating apparatus tested were: The simple hydrogen sulphide tester, chosen for this work and designated in this paper as standard apparatus;; the Referees apparatus; the Young's sulphur and ammonia test apparatus; the small drying-tower form, and a large Woulff bottle. Only one very simple form of the impinging type was tested; and a single penetration apparatus, devised in the bureau, was used. The variation in the tests with different forms of apparatus is largely due to the variation in intensity of the gas currents and their direction in relation to the paper. In the small drying tower the test paper was suspended close to the rubber stopper bearing the burner and a much larger proportion of the gas came in contact with the paper than in the other forms of apparatus. Although the Woulff bottle had a larger capacity than the Referees apparatus it consistently gave a stronger test than the latter, showing that size alone is not a determining factor; the shape of the apparatus and the location of the paper relative to the inlet and outlet have an important influence. It has been generally recognized that a test in which the gas impinges on the paper is more sensitive than one in which the gas does not impinge; this is due to the better opportunity for contact of the gas with the reagent on the paper and to the small area within which the lead sulphide is concentrated. And a similar increase in sensitiveness is accomplished by causing the gas to be tested to pass through the paper, as is done in the penetration apparatus described. This increase in sensitiveness due to impingement of gas on paper seems to have been overestimated by some, however.

The important influence of the shape and size of the apparatus upon the result of tests made with it, makes clear the necessity of an exact specification of the form and size of the tester. It is therefore recommended that the specifications given for the apparatus which is used as standard in this work, be followed exactly in making the tests. When the test is made under definite conditions, the coloration produced is of quantitative significance as indicating the amount of hydrogen sulphide present in the gas. The results which are obtained by the procedure recommended as standard are shown to have the following significance. The test, if of one minute duration, will detect about 0.3 to 0.4 grain hydrogen sulphide per 100 cu. ft. of gas. But if the test is of 0.5 minute duration, about 0.45 grain of hydrogen sulphide is required to give a test; if extended to three minutes a gas of about 0.2 grain will give positive results. The Young's apparatus is slightly more sensitive than the standard form, but the Referees apparatus is less sensitive for it will scarcely detect 0.5 grain of hydrogen sulphide per 100 cu. ft. of gas when used with moist paper for three minutes at a rate of 5 cu. ft. of gas per hour.

The penetration apparatus is somewhat more sensitive than any of the forms of circulating apparatus. The sensitivity of the apparatus of the impinging type is variable, depending upon the rate of gas flow, distances of jet from paper, etc.; but under the most favorable conditions apparatus of this type is the most sensitive of all. No direct comparison can be made with the work of some of the previous observers, but it is certain that too great a sensitivity has been ascribed

to the procedures used by these experimenters. The commercial significance of the testing procedure recommended is pointed out. It is stated that many tests of similar severity and some a great deal more severe have been met regularly in the past, showing that the proposal is certainly not unreasonable. The method recommended for use is quick and convenient and gives reproducible results; and a simple and inexpensive form of apparatus is described which can easily be constructed by inexperienced persons without any sacrifice of the advantages due to exactness of specifications. The importance of conforming to the specifications, both as to the apparatus and the procedure in testing, is pointed out.

Recent Chemical and Metallurgical Patents

Copper, Lead and Zinc

Flotation of Carbonates by Previous Conversion Into Sulphides.—Since oils manifest a greater affinity for sulphides than for carbonates or oxides, Mr. JOSEPH T. TERRY, JR., of San Francisco, Cal., proposes by a patented process to convert such oxides or carbonates into sulphides and then recover the same by flotation concentration. The inventor has discovered that oxide and carbonate minerals of such metals as copper, lead, silver, arsenic, antimony, mercury, bismuth, tin, cadmium, etc., are superficially converted to sulphides by hydrogen sulphide gas, or water solutions of the same, and that these converted minerals are then readily separated from gangue by oil flotation. In a similar manner, the water-soluble salts of metals are converted to sulphides and made amenable to oil flotation. The process may be applied by grinding the ore in water, treating with hydrogen sulphide gas and agitated with addition of oil. The sulphides float and may be separated from the gangue and recovered for further reduction. (1,094,760, Apr. 28, 1914.)

Copper Hydrometallurgy and Electrolytic Precipitation.—In patents issued to Mr. GEORGE D. VAN ARSDALE, of East Orange, N. J., the inventor describes his preferred method of roasting, leaching and precipitating copper in ores. When the ore is rosted there should be enough sulphur present to provide at least two parts of sulphur for each part of copper, and the roast conducted so as to give the maximum amount of water-soluble copper compounds. These compounds are leached with acidulated water, the acid for the initial charge being added from an extraneous source. After the cycle of operations is well started the acid can be secured by adding liquor from a preceding operation, being generated in the course of the process. Following the first leaching operation, the ore is washed with a second solution, which is added to the first. If more copper remains, a third wash may be given, the resulting solution being precipitated on iron and run to waste. This waste of solution can be regulated to avoid accumulation of impurities in the circulating mill solution. The original solution obtained is precipitated electrolytically, using sulphur dioxide to prevent polarization by combination with oxygen at the anode, and reduce ferric to ferrous salts. The gas is added to the cells during electrolysis, serving to heat and agitate the solutions.

The hydrogen evolved at the cathode tends to combine with the sulphur dioxide, forming hydrogen sulphide which then reacts to form copper sulphide which will be precipitated with the copper. In order to avoid this, precipitation is continued only until about 80 per cent of the copper in solution is precipitated, after which it is found that further precipitation commences to throw out copper sulphide. With a 10 per cent solution of copper sulphate containing sufficient sulphur dioxide to prevent polarization and reduce ferric to ferrous salts, 10 amperes per square foot at between 0.7 and 1.2 volts is sufficient to effect precipitation of 80 per cent or the copper without throwing out sulphides. The original solution is approximately regenerated and used as before. (1,119,477-8, Dec. 1, 1914.)

Smelting Complex Zinc Ores.—A method of smelting ores containing zinc and other metals such as lead, copper, gold and silver, is patented by Mr. JAMES M. HYDE, of Berkeley, Cal. The fluxed charge of ore is smelted over a bath of slag or matte and out of contact with the gases of combustion used for producing the smelting heat. The zinc is volatilized, the lead reduced to bullion containing some of the precious metals, and the copper recovered as matte containing also some gold and silver. Two types of furnace adapted to the process are shown in vertical transverse section in Figs. 1 and 2.

Referring to Fig. 1, the furnace wall A encloses the heating chamber and retort structure B. The charge within the shaft K and retort B is heated by products of combustion from gas burners G, H and G″. The gases entering G and H have no access to the charge within the retort B, and the gas entering G″ plays directly on the layer of slag. Arches C permit the fused material to fill the lower portion of the furnace which is provided with tap-holes D, E and F, for slag, matte and metal respectively. Zinc vapors pass off through pipes M to condensers N.

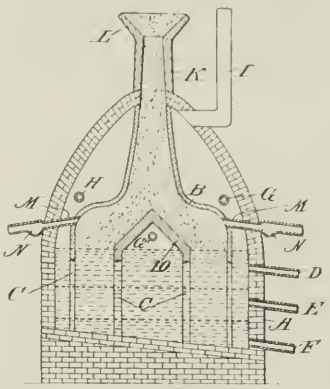


FIG. 1—FURNACE FOR COMPLEX ZINC ORES

In the modification shown in Fig. 2, the ore mixture is delivered through a hopper P′ to a tube L′ in which is a screw conveyor O′ to force the feed into the open-bottomed retort B′ extending transversely across the furnace chamber. There may be a number of such retorts suitably supported on a structure provided with open arches as in Fig. 1. The same tap-holes and condenser are provided.

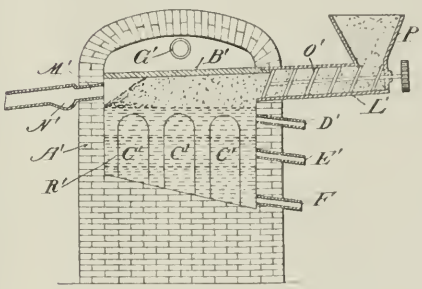


FIG. 2—FURNACE FOR COMPLEX ZINC ORES

In operation, the fluxed charge, either briquetted or loose, is fed into the retort where it is heated by the flame outside the retort. Volatilized zinc has a free exit to the condenser, and the fused materials fill the lower part of the furnace, from which valuable products containing the other metals are withdrawn. The process is claimed to offer economy in fuel, labor and mechanical wear and tear, as compared with present practice in retort furnaces, besides offering a possible means of treating mixed ores and recovering practically all the valuable metals. (1,118,012, Nov. 24, 1914.)

Mercury and Molybdenum

Extraction of Mercury.—A process for recovering mercury from its ores and other materials, is patented by Mr. E. BRYANT THORNHILL, of Gray Summit, Mo. The process was developed in connection with the recovery of mercury used for the treatment of high-grade silver ores at the Buffalo mill, Cobalt, Ont., but is appli-

cable to ores. The method is based on the solubility of mercury sulphide in a mixture of alkali sulphide and alkali hydroxide, and the precipitation of metallic mercury from solution by addition of aluminium dust. (1,119,377, Dec. 1, 1914.)

Extraction of Molybdenum.—According to a patent issue to Mr. Frederick D. S. Robertson, of Toronto, Canada, the ores of molybdenum can be treated for the production of molybdic tri-oxide by roasting at a temperature of about 800 deg. C. in the presence of an excess of oxygen. The volatilized product is collected in bags. The temperature in the bag-house must not exceed 120 deg. C. when woolen bags are used, or 90 deg. C. with cotton bags.

Data Concerning Platinum, the well known illustrated booklet, published by Baker & Co., Inc., Newark, N. J., has appeared in its thirteenth edition, with numerous new tables, illustrations and matter descriptive of various new appliances of platinum. There are 53 pages of descriptive matter of platinum stills for the concentration of sulphuric acid, platinum dishes, platinum parting apparatus, retorts, crucibles, combustion tubes, muffles, triangles, filter cones, platinum and platinum gauge electrodes, tongs, rods, etc. Concise useful rules follow on the use and care of platinum ware, as well as extensive tables of weights of platinum ware, sheet and foil, conversion tables, sulphuric acid tables, tables of specific weights, boiling points, etc. The whole book comprises 80 pages and is interestingly written and neatly printed and illustrated.

The Scientific Specialties Company is a new corporation with offices and show-rooms at 17 Madison Avenue, New York City. It will be the aim of the company to introduce new specialties in the chemical, metallurgical, physical and bacteriological lines, and to handle import orders for colleges, universities, etc. For this purpose a branch office has been established in Offenbach (Main), Germany. Radium and radium apparatus are one specialty of the firm.

The Industrial Instrument Company, of Foxboro, Mass., has mailed us its illustrated bulletins 86 and 91. Bulletin 86 describes the Foxboro differential recording gauges and orifice meters for measuring the flow of gases, about which we intend to give some further information in a future issue. Bulletin 91 describes the Foxboro recording and indicating dial-type thermometers, with several important recent improvements. Both bulletins contain typical and interesting records from the recorders in actual service.

Under Feed Stokers.—One branch, at least, of the iron industry has been benefited by the present business depression. Since the European war broke out orders aggregating ninety-nine of Hagan American Under Feed Stokers have been received by the George J. Hagan Company, Pittsburgh, Pa., from a number of the oldest companies in America to be used in varied industries from enameling light household utensils to heating heavy blooming mill ingots, so that the George J. Hagan Company has not only been able to keep its full force of employees occupied on full time and pay, but additional assistance in its engineering department has been required. For the Hagan American under feed stokers it is claimed that a cheaper grade of coal and less of it can be used to produce a given number of heat units and that these stokers are especially adapted to heating and annealing furnaces. Among those users who have given new orders recently are the Phillips Sheet & Tin Plate Company, Weirton and Steubenville Plants, National Enameling & Stamping Company, Scullin-Gallagher Iron & Steel Company, Crucible Steel Company of America., etc.

A Norwegian Electric Steel Plant

The Stavanger Electro-Staalverk A.S. has its offices in Stavanger, Norway, and its works at Jörpeland, across the fjord about ten miles east of Stavanger. At Jörpeland cheap electric power is abundant, being purchased from the hydro-electric development company at about $6.00 per mechanical horse-power year.

At Stavanger are some small shipyards, and also firms engaged in breaking up old steel ships. This furnishes a plentiful supply of old scrap steel, which has formerly been shipped to England and Germany,

FIG. 1—GENERAL VIEW OF STAVANGER ELECTRO-STAALVERK CO.

but is now basic material for the flourishing local steel industry. The capitalists of the ship breaking-up business are also largely interested in the electric steel plant.

The photographs show the plant at Jörpeland. Engineer Jacobsen is general engineer for the company. Mr. Th. H. Poulsson the manager of the works and Mr. Svensson metallurgist. The Siemens-Martin furnace has a capacity of four tons, and in it the scrap steel is melted by producer gas made from English coal. In about four hours the melted steel is transferred to a Roechling-Rodenhauser induction electric furnace, and

FIG. 2—CASTING FLOOR

there refined. The composition of the melted open hearth steel and of the refined electric furnace steel are about as follows:

	Open Hearth	Electric
Phosphorus	0.07	0.023-0.010
Sulphur	0.03	0.018-0.008
Carbon	0.10-0.15	As desired.

By adding ferro-alloys, various qualities of special steels, such as high-speed steel and magnet steel, are made.

The large foundry can turn out castings up to 8 tons in weight, by combining a heat in each furnace into one cast. The well-equipped forging plant produces rods and other shapes. Ingots and billets are being shipped

in considerable quantities to Sheffield, England, where they are forged and worked up into the finest "Sheffield Steel." This firm is selling large quantities of steel to England for motor parts for aeroplanes and automobiles; also a special quality of steel for hot-stamping, which is meeting with great success.

FIG. 3—FOUNDRY

The Stavanger Electro-Staalverk made a fine exhibit of its products at the recent Norwegian Centennial Exhibition at Christiania, and received a gold medal.

The success of the company is due to the combination

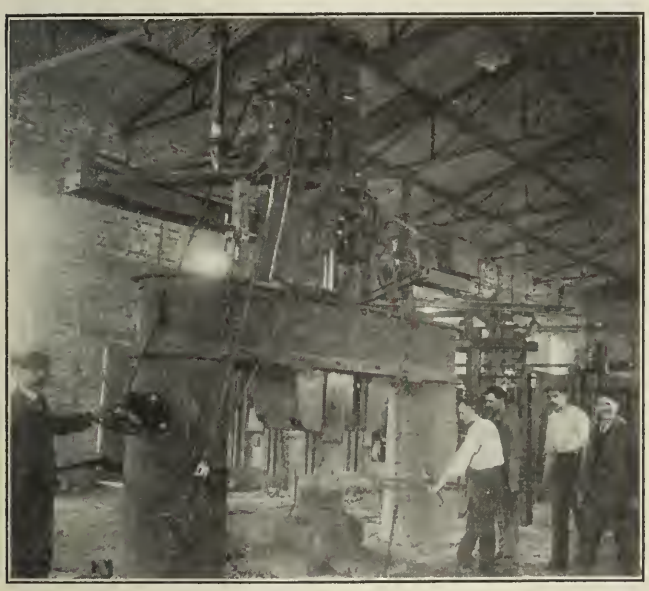


FIG. 4—FORGING DEPARTMENT

of the cheap supply of scrap steel, melting in the open-hearth furnace, refining in the electric furnace, cheap power, and able engineers and metallurgists in charge of the various departments of its works.

Personal

Mr. **H. F. Grondys**, representative of the Compania Minera de Oruro, Oruro, Bolivia, has been in Salt Lake City investigating metallurgical processes.

Mr. **H. W. Hardinge** has gone to Arizona for a three weeks' tour of the mining camps and to attend the American Mining Congress.

Mr. **Julius W. Hegeler** is president of the newly organized Hegeler Zinc Company, which succeeds to the business formerly conducted under the partnership of Hegeler Brothers. The company operates a zinc smelter at Danville, Ill.

Mr. **James M. Hyde**, of San Francisco, Cal., has been in Colorado on professional business.

Mr. **Woolsey McA. Johnson** has resigned as first vice-president of Johnson Electric Smelting Inc. His resignation will take effect on January 1, 1915. He will be

FIG. 5—CHEMICAL LABORATORY

connected with the company for the present in a consulting capacity and will remain a director.

Mr. **A. E. Keller**, of Denver, has gone to Ecuador to revise the mining and metallurgical accounting system for the South American Development Company.

Mr. **John L. Malm** has returned to Denver after a short trip east on professional business.

Mr. **J. H. Polhemus** has resigned his position as assistant to the president of the American Zinc, Lead and Smelting Company to accept a position as assistant manager of mines for the New Jersey Zinc Company.

Mr. **Walter Harvey Weed** has announced the removal of the office of the *Copper Handbook* from Houghton, Mich., to New York City.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

AQUEOUS BATH (ELECTROPLATING) *Continued*

655,111, July, 31, 1900, Andrew Plecher, of Savannah, Georgia.

Relates to portable apparatus for electrolytically decomposing solutions, such as water, into its components, hydrogen and oxygen. The apparatus consists of two parts of a vessel which when assembled is preferably of spheroidal shape. The parts may be of metal, suitably insulated, or of insulating material. The compartment in which hydrogen is evolved has twice the cubic capacity of the oxygen compartment. The compartments communicate with each other near the bottom, and have electrodes of either gold or platinum. Suitable outlets for the gases are provided, and an inlet for the solution to be electrolyzed, which may be dilute sulfuric acid.

664,550, Dec. 25, 1900, Henry L. Hollis, of Chicago, Illinois.

Relates to coating iron or steel objects with a protective coating of oxid of iron, and is an improvement

on his patent 621,084. The improvement consists in using an alkaline electrolyte, such as sodium hydroxid, passing a current therethrough with the iron object to be coated as cathode, whereby it is cleaned, then by a reversing switch changing the direction of current, making the iron object the anode, whereby it is oxidized. The electrolyte of sodium hydroxid has preferably a specific gravity of 1.25 to 1.40, heated to a temperature of 50° C. to 115° C., and with a current strength of 0.005 to 0.3 amperes per square inch of anode surface. The coated articles may then be heated in an annealing furnace for several hours at a temperature of 800° F. to 1400° F., which converts the coating to magnetic oxid.

665,784, Jan. 8, 1901, Henry K. Hess, of Philadelphia, Pennsylvania, Assignor to Herman J. Dercum, Trustee, of same place.

Relates to an apparatus for regenerating the electrolytes of two-fluid primary batteries, and consists of a lead lined tank containing a plurality of vitreous mercury troughs electrically connected as cathode, and a plurality of porous cells between the mercury troughs the porous cells containing lead as shot or scrap, or lead grids, connected as anode. The sulfuric acid electrolyte saturated with zinc is placed in the tank in contact with the mercury, and the reduced chromium solution placed in the porous cells. An electric current is passed which deposits the zinc in the mercury, liberating sulfuric acid, and re-oxidizes the chromium electrolyte. When the charge is regenerated, the mercury trays are removed, the zinc-amalgam pressed out, which may be pressed into amalgamated zinc electrodes, and the regenerated sulfuric acid and chromium electrolyte drawn off.

670,350, March 19, 1901, Botho Schwerin, of Munich, Germany.

Relates to a process of eliminating water or other fluids from solid mineral, vegetable, and animal substances, such as wood-pulp, starch-pulp, ground peat, disintegrated fruits, clay sludge, potatoes or beet-roots reduced to slices or pulp, distintegrated fish or flesh, crushed seeds, and the like, by the action of the electric current. The material to be treated is brought in contact with positive and negative electrodes by placing or moving it between the same while the current is passing. The molecules of water or other fluid diffuse from the solid particles toward the negative electrode where they are allowed to escape to the outside, for instance, by rendering the negative electrode permeable to liquids. The strength of current applied is dependent upon the nature of the fluid to be removed, and must be determined by experiments for each material. Mechanical pressure may be applied to remove some water and thereby reduce the current applied accordingly. For the apparatus used, see patent 670,351.

670,351, March 19, 1901, Botho Schwerin, of Munich, Germany.

Relates to apparatus for carrying out the process of freeing various materials of water described in his patent 670,350. It consists of two concentric cylinders, the inner electrically connected as the positive, and the outer as the negative, the latter being permeable, and may be of perforated sheet, or wire gauze, etc., and having an exterior covering of canvas or cloth. The inner electrode is supported upon a stationary shaft projecting into the apparatus. In the annular space between the electrodes is an insulated spiral, supported upon sleeves on the stationary shaft, and rotated by a pulley mounted upon the outer sleeve, thus moving the material forward. At the discharge end of the apparatus is a spring-pressed disk closing the discharge opening, and arranged to exert pressure against the material to keep it in firm contact with the electrodes and to press out some water through the permeable electrode.

670,510, March 26, 1901, William Friese-Greene, of London, England assignor to the Electrical Inkless Print-Syndicate, Ltd., of same place.

Relates to a method of electrically printing on paper, textile fabrics, etc., words, designs, etc., and is intended to replace the ordinary printing processes using ink or colors. The paper or other fabric is prepared by incorporating with it a photographic developer of the oxybenzene series, such as amidol, metal, or hydroquinon. The chemical may be applied in any suitable way, as by mixing with the paper pulp during the manufacture. The prepared paper is operated upon in a printing press or similar machine, the printing form or type being connected preferably to the negative pole. On passing the current the words or design to be printed appear upon the paper or fabric, and the operation may be performed at a rapid rate.

A variety of colors can be produced by this process, the color varying according to the substance with which the paper is prepared. When amidol is used, the paper should be washed in running water to remove the residual unchanged amidol.

Book Reviews

Coal Gas Residuals. By **Fred. H. Wagner.** 180 pages, 44 illustrations. Price, $2. New York: McGraw-Hill Book Company, Inc.

This book covers the handling of the gases of distillation to secure tar, naphthalene, cyanogen, ammonia, and benzol.

The treatment is detailed and practical costs of processes being frequently given, with estimates of probable profits.

The theories and processes of Dr. Feld are presented *in extenso,* and constitute a highly valuable source of information on advanced European practise, which American technologists will do well to study and to utilize.

Taken in the whole, it is a first-class book on a very timely subject.

Metallurgy of Copper. By **H. O. Hofman,** Met.E., Ph.D. Octavo (15 by 23 cm), xiv + 556 pages, 548 illustrations; price, $5. New York: McGraw-Hill Book Company, Inc.

Following his monumental work on general metallurgy, Professor Hofman has made the metallurgical world his debtor by a masterful work on copper. He is completing the series by revising his book on lead, and preparing treatises on gold and silver, and the minor metals.

This is a treatise on copper, for the modern copper metallurgist. In it he will find every branch of the subject considered, with copious references to the literature to enable him to push his studies further than the limits of this book. The compilation has taken an enormous amount of labor, and has been done with discrimination. The typographic errors are extremely few, considering the vast amount of data assembled. Professor Hayward, of Massachusetts Institute of Technology, assisted in the calculations interspersed through the work, which are both interesting and illuminating.

The discussion of bessemerizing of copper matte is very well done, particularly the thermal analysis. Throughout the work, drawings to scale are numerous, and comparative tables of practise in various plants are frequent. The work is everywhere "up to the minute." It is not so well suited for ordinary student reading, being so condensed and encyclopaedic, but will serve them well as a book of reference; it is a true *vade mecum* for the copper metallurgist.

Metallurgical and Chemical Engineering

A Consolidation of Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII | New York, February, 1915 | No. 2

PUBLISHED MONTHLY BY THE
McGraw Publishing Company, Inc.
James H. McGraw, President.
Secretaryship vacant.
John T. DeMott, Treasurer.
239 West 39th Street, New York.
Telephone Call, 4700 Bryant.
Cable Address, Metchem, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Colo.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; *for all other countries,* $2.50. (*European exchange,* 10 *shillings,* 10 *marks,* 12.50 *francs.*)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

New York, February, 1915

Editorial:
The Debt of Transcontinental Telephony to Metallurgy... 67
Progress in Ore-Dressing in 1914... 67
A Failure in Coking Coal Land Speculation... 68

Readers' Views and Comments:
Carbon Determination by the Combustion Method. By William W. Jennings... 70
Comparison of Electric Resistivities at High Temperatures. By Carl Hering... 70
High Temperature Experimental Furnace. By Walter R. Malm... 70
Tube-Milling Tonnage Calculation and Notes on Tube-Milling. By H. B. Lowden and A. H. Jones.....70 and 71
The Iron and Steel Market... 72
The Western Metallurgical Field... 73
The Non-Ferrous Metal Market... 75
The Presentation of the John Fritz Medal to John Edson Sweet 75
Hearing of the Proposed Amendment of the Patent Laws.... 76
Dinner to Frederick G. Cottrell... 81
Annual Report of the Bureau of Mines... 84
Handling Iron and Cinder at the Blast Furnace. By J. E. Johnson, Jr.... 85
Tube-Milling for the Flotation or Oil-Concentration Process. By W. B. Easton... 89
The Use of Hydrometallurgical Apparatus in Chemical Engineering (Conclusion). By John V. N. Dorr... 91
Metal Production Statistics for 1914... 98
American Institute of Mining Engineers... 98
Feldspar as a Possible Source of American Potash. By Allerton S. Cushman and George W. Coggeshall... 99
The Development of Continuous Counter-Current Decantation in Cyanidation of Slime. By W. J. Pentland... 105
Limitation of the Electric Furnace in the Manufacture of Steel Castings. By G. Muntz... 108
Presentation of the Perkin Medal to Edward Weston... 111
Pyritic Smelting at Mount Lyell... 116
Synopsis of Recent Chemical and Metallurgical Literature... 118
Recent Chemical and Metallurgical Patents... 120
Notes on Chemistry and Metallurgy in Great Britain.... 123
A New Continuous Filter... 125
An Examination of Fire-Bricks... 127
A Diatom Heat-Insulating Brick... 129
Paint Remover Patent Decision... 129
Obituary (Charles M. Hall and Theo. Armstrong)... 130
Personal... 131
Digest of Electrochemical U. S. Patents... 131
Book Reviews... 132

The Debt of Transcontinental Telephony to Metallurgy.

The opening of the telephone line from New York to San Francisco on January 25 is one of the most noteworthy engineering achievements of recent times and sincere felicitations from every American engineer are due to Mr. John J. Carty, chief engineer of the American Telephone & Telegraph Company, and his able engineering staff. To the readers of this journal this event signifies again the interrelation of arts and sciences and especially emphasizes the fact that after all every new engineering undertaking must rely very largely on metallurgical progress. A few figures on the New York-San Francisco line are suggestive. The length is 3400 miles so that during any telephone conversation 6800 miles of wire are reserved exclusively for the speakers at the two ends. There are four hard-drawn copper wires of No. 8 B.W.G. gauge, from which two physical circuits and one phantom circuit can be derived. The total weight of copper in one circuit of two wires is 1480 tons. Of course, the whole thing would have been impossible without the high-conductivity copper obtained by electrolytic refining. But this was not enough, as Pupin's induction loading coils play an important part in the transmission, and in the construction of these coils iron plays an important part and the iron must have very peculiar properties; it must be as fine as a hair (0.004 inch in diameter) and must be insulated at that, and it must have very distinct electrical and magnetic properties. Some of the very best metallurgical talent in the world was employed in the solution of the problems involved. The work of designing and erecting the line has been enormous, but the achievement has been commensurate with the efforts.

Progress in Ore-Dressing in 1914

In the development of the art of ore-dressing during the past year, two tendencies were most distinctly marked. The first of these was in the direction of increasing the size and capacity of units of concentrating machinery. The second was the adaptation of flotation processes to an increasing number of types of ore.

The Utah Copper Company has for some time been making use of double-deck roughing tables having a very large capacity. The rough concentrate from a number of these tables is cleaned on a single table of the Wilfley type. A number of manufacturers are now offering special types of tables having unusually large capacity. One of the most interesting plants using a new type of an old machine is the slime concentrator of the Anaconda company, where twenty-deck buddles were installed for the purpose of handling large quantities of low-grade slime at low cost.

The engineers responsible for the development of concentration methods that have made possible the exploitation of the low-grade copper ore of the Utah Copper Company, designed a mill on similar lines for the treatment of the low-grade gold ore of the Alaska Gold Mines Company. This application of modern copper concentrating methods to gold ore is one of the most interesting developments of the year, but the conditions are unusual and the venture is expected to prove successful. The Alaska ore is amenable to this method of treatment because the gold occurs almost entirely in coarse particles. Jaw and gyratory breakers will be used for coarse crushing, and two series of rolls will finish the grinding prior to rough concentration. The next step in grinding will be done by tube or pebble mills, followed by the usual methods of concentration and amalgamation applicable to finely ground material. It will be observed that the almost universal practice of using stamps in connection with so-called free-milling gold ores has been abandoned in this instance.

Flotation concentration has now been in use by the Butte and Superior Copper Company long enough to demonstrate that the process, as specially modified by J. M. Hyde to fit the needs of that ore, is a marked success. Not only has the percentage recovery been increased by the adoption of the process, but the grade of concentrate also has been raised. It is understood that a special adaptation of flotation concentration has been developed at Anaconda to supplement the general milling scheme. The results are such as to make flotation appear a close competitor with the roasting-leaching process already perfected by the company's staff, and for which a 2500-ton plant has been erected. It is possible that flotation may be adopted for treating slime of current production, leaving the old accumulations to be treated in the leaching plant.

Experiments with flotation processes have been conducted by many prominent, and even minor, companies during the past year, and it is likely that the coming year will see a wider adoption of the process. It is expected that new installations in the large copper mills will effect so much higher recovery than is now being made as to materially augment copper production in the Rocky Mountain and Southwestern regions. Some engineers confidently see the doom of the vanner in the success of flotation, and if this be accomplished no one will regret to see the abandonment of the acres of vanners now necessary to handle the slime in the large copper mills.

A number of American engineers are contributing to the development of the art of flotation concentration. Mr. J. M. Callow has brought out a machine in which the air necessary for flotation of the oiled sulphides is introduced into the pulp under pressure through a canvas diaphragm. Mr. John D. Fields is sponsor for another process that has been tested in a number of mills, and was to have been adopted experimentally by the Ohio Copper Company, if that concern had not been overtaken by financial troubles. Mr. Henry E. Wood has developed still further his machine for surface-tension flotation, which is successfully applied to a number of types of sulphide ore. Mr. J. H. Haynes has made some novel improvements that look promising, having given encouraging experimental results. The Macquisten process has been in profitable operation at the Morning mill of the Federal Lead Company, at Mullan, Idaho.

In Australia, Horwood, Lyster and Bradford have brought out special modifications of practice for making a differential separation of sulphides.

Another modification of oil concentration, the Murex process, has been adopted on a commercial scale abroad and is being tested in this country. In this process finely ground magnetite is mixed with oil, which is then thoroughly mixed with the ore pulp to be treated. The presence of the magnetite in the oil permits the oiled metalliferous minerals to be removed by means of an electromagnet. The special field for this process seems to be in concentration of oxide and carbonate ores of lead and copper, and possibly in the differential separation of galena, pyrite and blende. In Germany it has been used successfully for recovering fine galena from slime containing much heavy spar. In Spain it is being used for the concentration of copper carbonates and oxides. Another patented scheme for floating oxide and carbonate ores involves their prior conversion, superficially, at least, into sulphides by treatment with hydrogen sulphide.

The art of flotation concentration should be rapidly developed when the status of flotation process patents is finally determined through the litigation now pending. Minerals Separation has succeeded in getting the United States Supreme Court to review the decision of the Ninth Circuit Court of Appeals in its case against James M. Hyde, and when the final decision is given, metallurgists will draw a breath of relief and progress will be rapid. It is regrettable that our patent procedure is so frightfully cumbersome.

Broadly speaking, the art of ore-dressing is becoming more complicated and more highly developed, and is constantly making it possible to treat materials that formerly were outside the realm of concentration. Professor Robert H. Richards has suggested that great profit is to be gained by placing high-class men in charge of the classifier departments of mills. In this regard it is certain that as we adopt new processes depending on principles not hitherto used, it will be more and more essential to employ high-class men in charge of ore-dressing operations; men who thoroughly understand what they are trying to accomplish, who know the principles involved, and who are capable of checking their work by the most carefully conducted tests.

A Failure in Coking Coal Land Speculation

Since January 18 the county court of Fayette County, Pennsylvania, at Uniontown, has been busy appointing receivers. On that date the First National Bank of Uniontown was closed by the federal banking authorities and immediately thereafter the receiverships began, for Josiah V. Thompson and many of his associates. Mr. Thompson's liabilities are stated at $22,000,000 while his assets are rated at $70,000,000. The interrelations of Mr. Thompson, his associates and various

corporations are so intricate and manifold that even a brief outline cannot here be attempted. There were partnerships, mortgages, options, promissory notes and other arrangements so extensive that Mr. Thompson, the central feature in all, and the president of the bank that was closed, is said to have been held at work twenty hours a day for a long time past keeping the financial and other machinery in operation. Finally the break came and it may be years before all settlements are completed.

While the structure that has been placed under the protection of the law until the engineers can repair its weak points or dispose of its parts is very complicated, the principle underlying the involvement is simple. Changes have occurred in the practices and ambitions of the steel trade of which the Thompson party was ignorant or became cognizant of when it was too late to protect themselves. A precedent was trusted when conditions had changed.

Mr. Thompson was a speculator in coking coal lands and carried with him almost the entire community which had money to invest. Almost the entire acreage in the regular Connellsville or "old basin" was acquired many years ago by merchant-coke interests or blast-furnace interests at relatively low prices per acre. In the latest period of its exploitation a few fortunes were made by farmers who had not earlier sold out. Just at the close of the last century the expanding needs of the iron industry required more coke and the lower Connellsville or "Klondike" was opened, and many fortunes were made. It was the spirit of the times that a large consuming interest should be provided with its raw materials for many years to come, and soon the Klondike was entirely pre-empted. Mr. Thompson, who had been prominent in the development, then turned his attention to the recognized extension of the seam across the Monongahela River into Greene County, believing that as the iron industry expanded it would be necessary for this coking coal also to be developed. His early purchases were at relatively low prices and his sales were by no means unimportant. They profited him while the buyers found themselves in fair position to ship coal or make coke. Year by year, however, Mr. Thompson paid higher and higher prices, whether to protect his market in selling coal acreage or through belief in the inherent value of the purchases it may not be safe to attempt to judge. The total acreage in which he is now interested directly or indirectly is estimated at not far from 200,000 acres in coal seams that promise to yield from 7000 to 9000 tons of coke per acre. This represents an amount of coke equal to the maximum shipments of the Connellsville and lower Connellsville regions for about three-quarters of a century.

In recent years the carrying of these speculative holdings has been expensive. It was necessary either that frequent sales should be made from the aggregation, at good profits, or that the recognized value of the coal, from the banker's standpoint, should increase steadily so that borrowings could be increased. Of late the sales have been infrequent and it seems to have been impossible to negotiate additional loans.

The operation was well planned in the light of fifteen years ago, for then there was no recognized competition for the Connellsville coking coal seam. It was the disposition of large blast furnace interests to fortify themselves for the future by acquiring ore and coking coal in the ground. The beehive-oven practice of the day naturally involved the acquisition of a large track of coking coal in the ground, for the ovens were located over the coal and enough coal had to be provided to give them a fair life.

While the development of by-product coking has involved many sad experiences, showing that the retort ovens also have their requirements as to the character of the coal to be carbonized, it is well established that the retort oven can draw from many districts, and of particular importance is the fact that since the retort oven is always located at the blast furnace, for well-known reasons, it is immaterial whence the coal comes so long as it is of the proper quality. Indeed, the builder of a by-product plant may prefer not to purchase a coal acreage at any price, but rather to remain independent and select his fuel as he proceeds—and learns.

The coal-shipping industry, being overdeveloped already, has not permitted any large development at anything but rock-bottom prices for the coal seam, and thus there has been little absorption of Greene County coal in that direction. It may be mentioned that one of Mr. Thompson's earliest customers, and his largest, the Pittsburgh Buffalo Company, has been in receivers' hands for some time. As to the use of the coal for coking purposes, styles have changed in the industry and therefore the object for which the Thompson coal holdings were accumulated could not be successfully carried out.

Apart from these purely technical considerations, it is well to reflect that there must be a limit somewhere to the activities of a steel-producing company. Even a corporation cannot do everything and do it well. Twenty years ago it was common for one company to make the coke and another to mine the ore. A third interest transported the ore, and a fourth interest quarried the limestone. Then the blast furnace assembled its raw materials and sold pig iron. There were steel mills that bought pig iron and sold billets, and "finishing mills" that rolled the steel. Since then vertical integration has become the rule. But the steel mill does not stop in its finishing where it stopped ten years ago. One prominent steel producer builds railroad cars. Several make cold-rolled shafting, car axles and the like. The largest steel-producing company in the world makes and sells automobile-engine flywheels. All the steel producers are called upon for heat treatment and for alloy steels. There is plenty to keep them busy, and to absorb their capital, without their mining coal or investing in coal lands. There was a time when such investments seemed necessary for defense but that time is past. Whether the Uniontown party did not know this, or acquired the information too late for it to be of service, is a detail in which the general public has no particular interest.

Readers' Views and Comments

Carbon Determination by the Combustion Method

To the Editor of Metallurgical & Chemical Engineering.

A good scheme to reduce the cost of the determination of carbon in all metals and alloys in which the combustion method is used is as follows. The combustion boats after being used once or twice are no good for further use, but if they are cleaned of the insoluble fused mass, left after a carbon determination, they can be used again.

Several chemical houses have on sale electric polishing heads which with a high velocity (2000 to 3000 revolutions per minute) and fitted with a small emery wheel, the edges of which must be rounded, can be used to advantage to grind the fused mass out of the boats so that they can be used again. This wheel does not get into the end of the boat, but the small amount of the fused mass that is left, being carbon-free, would not vitiate the results.

These combustion boats are usually imported. With the grinding head, and with proper care in cleaning, one boat can be used to determine a great number of carbons. Care must be taken in cleaning them not to let the emery wheel touch the ends of the boat, for this would cause them to break and chip.

Wm. W. Jennings.

Electro Metallurgical Co., Glen Ferris, W. Va.

Comparisons of Electric Resistivities at High Temperatures

To the Editor of Metallurgical & Chemical Engineering.

Sir:—My attention has just been called by a friend to a draughtsman's error in chart 2 of my article, under the above heading, page 24 of your January issue, which I desire hereby to correct.

The curve for lead in chart 2 should of course correspond with the one in chart 1, hence the line approaching the short vertical melting point line should have been drawn to the bottom instead of the top, and the line after the melting point should have been drawn from the top instead of the bottom. The vertical line itself is correctly placed.

As this curve for lead is reproduced in chart 2 from chart 1 merely to show the proportions of the two scales, the error is not important except in that it gives the impression that the resistivity of lead falls upon melting, like bismuth, while as a fact it rises, as is correctly shown in chart 1.

Bismuth, antimony and perhaps Rose metal are the only three of the metals which fall at the melting point, all the others rising. It may be, however, that some of the non-metallic materials like those in charts 3, 4 and 5, fall upon melting, like bismuth; no data confirming this have come to my attention.

Carl Hering.

Philadelphia, Pa.

High Temperature Experimental Furnace

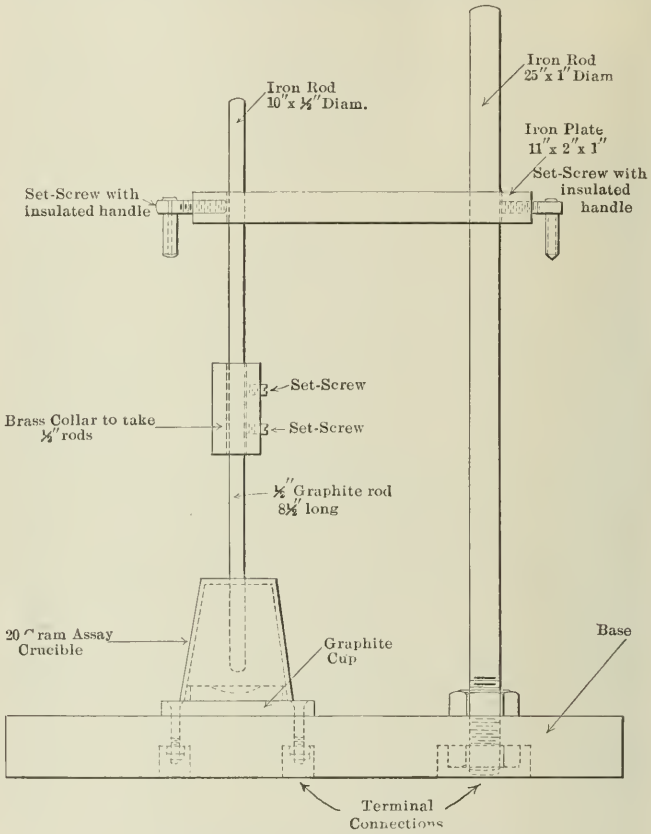
To the Editor of Metallurgical & Chemical Engineering.

Sir:—The following article describes a very simple and easily constructed experimental arc furnace which came under my observation while visiting the high-temperature laboratory of the Noble Electric Steel Company, at Heroult, Shasta County, Cal.

The furnace is especially adapted for the fusion of ferro-alloys, the melting point being reached within several seconds after applying the current.

The accompanying figure shows the furnace in its simplest form.

The base consists of a slab of any suitable refractory insulating material such as slate or marble. The standard is made by bolting an iron rod to the base at one end. A sliding arm, held in place by a set screw, holds the adjustable electrode. This electrode, which consists of a rod of graphite or carbon, slides through a hole in the bottom of an inverted 20-gram assay crucible



EXPERIMENTAL ELECTRIC FURNACE.

until it reaches within any desired distance from the bottom electrodes. The crucible serves the double purpose of protecting the eyes of the operator from the rays of the arc, and at the same time stopping any circulation of air which would tend to oxidize the electrodes. The bottom electrode is also made of graphite or carbon but in the shape of a disk in which is cut a cup for receiving the charge. Insulated handles of hard rubber are put on the set-screws so that the electrode can be raised or lowered while the furnace is in operation.

The furnace may be used on 110 or 220 volts taking from 30 to 50 amp while giving a ½-in. arc.

On starting a fusion it is better to cover the charge with powdered charcoal so that the crucible will fill with hot gas at the instant that the arc jumps.

Walter R. Malm.

San Francisco, California.

Tube-Milling Tonnage Calculation and Notes on Tube-Milling

To the Editor of Metallurgical & Chemical Engineering.

Sir:—Fine grinding efficiency in tube mills, although of such universal importance, has thus far not proved

amenable to mathematical treatment, and although many other operations in the cyanide process are susceptible of fairly exact mathematical expression, tube-milling at all plants is, in the early stages of their operation, experimental. Many disconnected data are scattered throughout the technical press and although it is useful, the time would seem to have arrived when some of the phases of this problem could be given mathematical form. As a step in the right direction, Mr. Cunningham's contribution on page 22 of your January issue should create a lively interest, and it is hoped it will elicit much helpful discussion.

From Mr. Haynes' remarks I am forced to conclude that he does not consider the advantages of the closed circuit as by any means well settled, and were many others of a like opinion, Mr. Cunningham's contribution would be of little interest. However, I do not think Mr. Haynes' attitude is shared by any great number of cyanide operators and I do not feel that an analysis of his arguments will bring many to his point of view.

Mr. Haynes errs in placing too much weight upon *percentage* as a factor of gross tube-mill feed. What the operator is after is the percentage of the initial feed (net feed) which is ground to the desired fineness, and what gross feed the tube-mill handles is of very minor consequence to him as long as he feels he is securing a satisfactory net result. Theoretically, the tube mill should do its best work when it is relieved of the slime as soon as possible after it is produced, and this is the effect of the closed circuit from the very reason that the circulating feed (gross feed) is so large in proportion to the net feed.

To make this clear, let us add another line to his table II to exhibit the time element. The charge will maintain a substantially even level within the mill under all conditions, being determined by the level of the discharge opening, and any increase in gross feed will reduce the time any given particle is within the mill. The figures added to Mr. Haynes' table (we may conveniently call them minutes) have been based on this assumption, 80 tons being taken as 100 minutes, 109 tons as $80/109 \times 100 = 73$ minutes, and so on.

EFFECT OF VARYING TONNAGE IN TUBE-MILLS

Tons feed 24 hours.....	67	80	109	217	239	570	693
Per cent minus 200-mesh in discharge 30.03	30.15	20.04	16.56	16.00	10.28	8.09	
Relative time pulp is in tube-mill	119	100	73	37	33	14	12
Tons minus 200-mesh in discharge 20.12	24.10	21.84	35.93	38.24	58.59	56.06	

The time element as given above shows very distinctly why the "per cent minus 200-mesh in discharge" appears unfavorable with the large gross feed. The time a particle is exposed to grinding during one passage is but 14 minutes if it is part of the 570-ton feed, as against 100 minutes in the case of the 80-ton feed. With the large feed the particle may pass through the circuit a number of times if necessary, but many other particles may be reduced to the desired size in the first passage, after which they are immediately removed. Why keep such particles within the mill for 100 minutes when 14 minutes will suffice? Better exert the energy on other particles which are still too large. The closed circuit accomplishes this automatically.

The addition to table II merely serves to emphasize and explain what can be seen by inspection of the table as it appears in Mr. Haynes' discussion. I refer to the percentage of initial feed reduced to minus 200-mesh. Under 109 tons we find 21.84 tons, and under 570 tons we find 58.59 tons. That is, we have increased the feed five times to increase the finished product three times. But this does not necessarily indicate bad practice. On the contrary, inspection of the figures shows that to get 58.59 tons of finished product direct from 109 tons of feed about three tube mills would be necessary. From 109 tons, 21.84 tons were finished. This leaves 87 tons. From 80 tons (second column of the table) 24.10 tons were finished. This leaves 56 tons oversize and 46 tons finished, so that we would need a third tube-mill.

There can be no question as to which is the better result. A tube-mill consumes the same power regardless of how rapidly the pulp passes through it, and power is the large item in the cost of tube-milling. As in everything else, there is a point beyond which it is not economical to go in increasing the return feed, as wear and tear of classifier, cost of elevating the return, etc., come into play; but I do not think these factors set the limit in the case under consideration, but rather the direct flow of sands through the tube without being subjected to grinding.

What Mr. Haynes bases his arguments upon are conditions in which the tube-mill is overloaded, and in such cases considerable plus 200-mesh must overflow the classifier weir. These conditions are undoubtedly too common. In fact, he says at the end of his article: "Absolutely the only way to obtain a larger percentage of minus 200-mesh material in the final product is to increase tube-mill capacity," and in this I am in accord with him; but the increase can be brought about with fewer tube-mills if operated in closed circuit than if in series. In a large installation the series arrangement may occasionally work out to advantage by reason of the ability to suit the grinding conditions to the particular feed, which will differ in the second mill from the first; but Mr. Haynes' own figures show conclusively the superiority of the closed circuit, although he attempts to prove the opposite by them.

I believe the closed circuit in tube-milling is with us to stay, just as it is in roll-crushing, and that Mr. Cunningham's formula will be found useful by many operators.

H. B. LOWDEN.

Denver, Colo.

* * *

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I have read Mr. Justin H. Haynes' article in your issue of January 5, entitled Tube-Milling Tonnage Calculation and Notes on Tube-Milling, also Mr. Noel Cunningham's article on Calculation of Returned Feed to Tube Mills.

Mr. Haynes advocates tube mill capacity sufficient to grind the entire feed to desired fineness in one passage through the tube, claiming that the closed circuit is a mistake with no advantages. This does not seem to figure out from his own table, No. 2 on page 11, which contains the data given in Table I.

TABLE 1—EFFECT OF VARYING TONNAGE IN TUBE MILLS

Tons feed 24 hrs.	67	80	109	217	239	570	693
%—200 mesh in discharge	30.03	30.15	20.04	16.56	16.00	10.28	8.09
Tons—200 mesh in discharge	20.12	24.10	21.84	35.93	38.24	58.59	56.06

In accordance with this table it would seem that with 67 tons initial feed and the once-through process we would expect 20.12 tons, or 30 per cent, to pass 200 mesh; while should we run the mill on a closed-circuit basis, with 67 tons initial feed, in accordance with the table, when the return has built up to 570 tons we would have 67 tons overflowing the Dorr—58.59 tons of which would pass 200 mesh, or an overflow of which 87.15 per cent would pass 200 mesh.

Mr. Haynes states that it is no exception for a tube mill run in closed circuit to have a total feed of 7 times the initial feed. I feel that this condition is greatly exaggerated, Mr. Cunningham's deductions being much nearer the true condition.

Until a short time ago we had figured tube mill total feed, from screen analysis, about as Mr. Cunningham describes, afterward changing to calculation from plus 28 mesh material showing in feed from batteries which

Table III

Mesh	Battery discharge Tonnage by Weighed Sample			Battery tube feed Tons by Weighed Sample			Battery Dorr overflow Tonnage by Difference between Battery Discharge and Battery Tube Feed			Tube mill discharge Tonnage by Battery Feed and Return Feed			Return feed Weighed Feed			Return Dorr overflow Tonnage Battery Feed to Tube			Dorr overflow general Battery Discharge Tonnage		
	%	% Cumulative	Tons	%	% C.	Tons	%	% C.	Tons	%	% C.	Tons	%	% C.	Tons	%	% C.	Tons	%	% C.	Tons
10	8.2	8.2	6.02	8.2	8.2	5.51															
14	12.3	20.5	9.03	13.1	21.3	8.80															
20	11.8	32.3	8.66	12.2	33.5	8.19															
28	12.2	44.5	8.95	13.1	46.6	8.80				.25	.25	.32	.42	.42	.25						
35	8.9	53.4	6.53	9.8	56.4	6.58				.75	1.00	.96	1.41	1.83	.85						
48	7.9	61.3	5.79	9.1	65.5	6.12				3.125	4.125	3.98	6.08	7.91	3.66						
65	5.1	66.4	3.74	7.0	72.5	4.70	tr			7.875	12.00	10.03	13.17	21.08	7.93						
100	5.0	71.4	3.67	10.0	82.5	6.72	2.5	2.5	.155	21.625	53.625	27.55	34.75	55.83	20.90	1.375	1.375	.92	1.375	1.375	1.01
150	4.4	75.8	3.23	10.5	93.0	7.05	9.125	11.625	.565	26.25	59.875	33.42	30.58	86.41	18.40	13.75	15.125	9.24	11.25	12.625	8.26
200	2.2	78.0	1.61	2.2	95.2	1.48	6.0	17.625	.372	8.5	68.375	10.83	5.42	91.83	3.26	10.625	25.75	7.14	7.875	20.5	5.78
—200	22.0	100.0	16.15	4.8	100.0	3.23	82.375	100.0	5.108	31.625	100.00	40.29	8.17	100.00	4.92	74.25	100.00	49.9	79.5	100.00	58.35
Total Tons			73.37			67.18			6.2			127.38			60.21			67.2			73.4

does not show in tube mill discharge, as shown from the screen analysis and deductions in Table II.

TABLE II

Mesh	Battery discharge Cumulative %	Battery discharge %	Tube mill feed %	Tube mill feed % C.	Tube mill discharge %	Tube mill discharge % C.	Dorr overflow %	Dorr overflow % C.
10	10.3	10.3	5.4	5.4	...	...	...	...
14	10.0	20.3	5.2	10.6	...	...	...	...
20	10.2	30.5	5.3	15.9	...	...	...	...
28	11.3	41.8	5.9	21.8	...	...	...	...
35	7.7	49.5	4.9	26.7	1.0	1.0	...	...
48	7.1	56.6	6.5	33.2	3.1	4.1	...	...
65	5.6	62.2	8.1	41.3	6.5	10.6	...	...
100	6.0	68.2	20.0	61.3	20.0	30.6	1.0	1.0
150	6.6	74.8	24.4	85.7	28.6	59.2	12.5	13.5
200	4.0	78.8	7.8	93.5	12.7	71.9	14.2	27.7
—200	21.2	100.0	6.5	100.0	28.1	100.0	72.3	100.0

Tons crushed per day 500. Feed per mill 62.5 tons.

DEDUCTION FROM COARSE MATERIAL

In the battery discharge there was 41.8 per cent, or 26.12 tons, which did not show in tube mill discharge. This material was represented in total tube mill feed by 21.8 per cent. As we know this 21.8 per cent is represented by 26.12 tons, the 100 per cent feed should amount to 119.8 tons.

Total feed ..... 119.8 tons
Initial feed ..... 62.5 "
Return feed ..... 57.3 "
Ratio of return..... 0.92 to 1 ton

DEDUCTIONS FROM SAME BY CUNNINGHAM'S FORMULA

$$a = 21.2$$
$$b = 6.5$$
$$c = 28.1$$
$$d = 72.3$$
$$B = 62.5$$
$$T = X$$

$$\frac{T}{B} = \frac{d-a}{c-b} \text{ or } \frac{X}{62.5} = \frac{51.1}{21.6} \text{ or}$$

$T = 146.8$ tons total feed
62.5 initial feed
84.3 return feed
Ratio of return 1.35 to 1.

Not being entirely satisfied with deductions from screen analysis, a vertical baffle was made to divide a Dorr duplex classifier into two separate sides, or machines, running feed from the battery to one side and the tube mill discharge to the other side, taking from the discharge from both sides over a given time samples for tonnage by weight and screen analysis. Table III gives the results:

From the tabulated deductions we have:

Tons total feed..... 127.38
Tons initial feed..... 67.18
Tons returned feed..... 60.20
Ratio of return..... 0.91 to 1

I think the error in Mr. Cunningham's method is due to disregarding the coarser than 200 mesh material, which does overflow as finished product.

While I feel that tube mills in series have advantages, it is hard to accept Mr. Haynes' assertion that no advantage is had by mills working in closed circuit over the once-through method when mills are in parallel.

I would like to say in closing that the method of figuring tube mill return from the known tonnage in battery discharge, not showing in tube mill discharge which checks out very close to the actual figures from weighed samples, originated with Mr. F. C. Reynolds, who has charge of our experimental work.

A. H. Jones,
Mill Superintendent.

Belmont Milling Company,
Tonopah, Nevada

The Iron and Steel Market

At the end of January the steel industry finds itself in no better position than at the begining, but the improvement that occurred during December has been maintained. The course of the market in January admittedly has furnished disappointment, not only because hopes were entertained, but also because expectations had been entertained that after the early days of January the December improvement would be continued.

The steel mills have operated during January at an average rate of fully 45 per cent of capacity, against an average of not more than 35 per cent during November and December. The current orders are of a miscellaneous character, there being no marked demand in any direction. There does not seem to be any replenishment of stocks in the hands of jobbers or manufacturing consumers. Such stocks had been subject to successive reductions, the last being occasioned by the tightness of money late in the old year, so that consumption was doubtless in excess of production in November and December while now consumption is at the same rate but production is somewhat heavier.

During the last five months of 1914 there was practically no buying by railroads. In the past month there has been an improvement, but viewed at long range the railroad buying is still very light.

Export demand is running quite largely to war material, both in the regular products of the steel industry and in the manufactured goods of its customers. The steel industry's exports are at record rate in barb wire, for instance, although the normal demand for barb wire from neutral countries has greatly decreased. Exports of lathes, motor cars and other things involved in war or the manufacture of implements of war are heavy. The latest export statistics are for November, showing 141,000 gross tons of iron and steel against 147,000 tons in October and an average of 141,000 tons a month during the first seven months of 1914.

It is clear that the steel market has not, thus far at least, responded as might naturally be expected to the great improvement in fundamental conditions, the heavy

export demand resulting during January in an enormous favorable merchandise trade balance, and the failure of foreign holders of American securities to dump them in our market, the result of these factors being a decline in exchange on London to below par while money for ordinary commercial purposes has become easy. In the circumstances the steel trade should be more prosperous than it is. There are hopes that the market will gradually broaden but there are no concrete developments in the steel market itself sufficient to support a a theory that it will.

A very sharp advance in spelter prices towards the close of the month created great excitement in the galvanized sheet trade, and prices advanced sharply, some mills, indeed, withdrawing from the market entirely until more settled conditions should develop in the spelter market. At the middle of October spelter sold at but a shade above 4½ cents, East St. Louis. At the end of the year it stood at 5½ cents, but in the week beginning January 18 it advanced from 6 cents to about 7 cents. A change of one cent a pound in the cost of spelter is commonly computed to mean a change of $3 per net ton in the cost of making galvanized sheets.

Pig Iron

The pig iron market has been quiet the past month, but prices have been well maintained. A general though somewhat restricted buying movement had occurred in northern iron late in the old year and the northern furnaces are in at least as good position as a month or two ago. The southern situation is anomalous. There was no general buying movement in southern iron, such as has always accompanied or even preceded a movement in northern iron. At the same time only two or three southern producers are free sellers, others holding to quotations that cannot let them into the market. Production has shown no distinct tendency to increase or decrease. The market is quotable as follows: No. 2 foundry, Birmingham, $9.50; delivered Philadelphia, $14.45 to $14.95; f.o.b. furnace, Buffalo, $13; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13; at valley furnaces (95 cents higher delivered Pittsburgh) Bessemer, $13.75; basic, $12.50; Nor. 2 foundry and malleable, $12.75 to $13.25. Ferromanganese on contract is nominal at $68, Baltimore, contracts being subject to embargo provisions that have not been thoroughly worked out. Prompt lots can usually be picked up at $75 to $80.

Steel

After covering nearly all consumers of billets and sheet bars for longer or shorter periods, usually the first quarter of the year, at low prices, averaging about $18.50 for billets and $19 for sheet bars at maker's mill the mills began to advance prices in January, Pittsburgh mills to $20 for billets and $20.50 for sheet bars and Youngstown mills by smaller amounts. Rods have stiffened to $25, Pittsburgh and some mills will not meet this quotation.

Finished Steel

Current quotations are as follows for ordinary deliveries, quotations being f.o.b. Pittsburgh unless otherwise noted.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.10c.

Shapes, 1.10c.

Steel bars and bands, 1.10c., base; hoops, 1.20c. to 1.25c.

Refined iron bars, Pittsburgh, 1.15c.; common iron bars, 1.12½c., Philadelphia; .97½c., Chicago.

Sheets, blue annealed, 10 gage, 1.30c.; black, 28 gage, 1.80c.; galvanized, 28 gage (uncertain), 2.90c.; painted corrugated, 28 gage, 2.00c.; galvanized corrugated, 28 gage, 2.95c.

Tin plate, nominal price, $3.20 for 100-pound cokes; large lots at $3.10 or possibly less.

Steel pipe, ¾ to 3-in., 81 per cent off list.

Steel boiler tubes, 3½ to 4½-in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Cold rolled shafting, 68 per cent off list.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Chain, ⅜-in., proof coil, 3.00c.

The Western Metallurgical Field

Spelter

The apparent steady improvement in the spelter market, as reflected by the upward trend of prices to six cents at St. Louis, is stimulating activity among producers of that metal. The outlook is regarded as very promising, and seven-cent spelter is freely predicted as a possibility before the close of the year. With the improvement in conditions, large producers are resuming operations. Butte & Superior is again operating its concentrating plant at Butte, and the new Timber Butte mill which treats ore from Senator Clark's Elm Orlu mine is also handling a large tonnage. The Granby company has begun smelting Joplin high-grade zinc ores at its new smelting plant at Roselake, Ill. This new smelter is situated near the coal fields of Illinois, in accordance with the tendency of building new smelters out of the natural gas districts of Kansas and Oklahoma. The furnaces are heated by producer gas, and the plant includes a sulphuric acid department.

The tentative proposal to erect on the Atlantic seaboard of this country a zinc smelter to reduce Australian concentrates which have been treated in Germany, received a set-back by the decision that the war does not abrogate the contract existing between the Zinc Corporation and Aaron Hirsch & Son. Australian producers have been placed in an awkward position by the fact that German smelters hold contracts for reducing the tremendous output of Australian concentrates. Apparently this precludes the possibility of smelting this material in the United States, or for that matter in England. The treatment of the Australian output in this country would be desirable from an economic point of view, as it would affect the whole industry in a manner favorable for the United States, but such an outcome does not appear possible now.

Joplin producers of zinc concentrates have been stirred recently by the belief that St. Louis quotations on spelter are not reliable and do not represent the true condition of the market. It is claimed that the quotations indicate prices for low-grade spelter, while the product of Joplin ore is of higher grade, commanding a higher price. As a consequence of these conditions, it is felt that Joplin producers do not get a price for their product commensurate with its grade. The Joplin Commercial club has been asked to attempt to rectify this matter by requesting the Merchants' Exchange of St. Louis to "adopt rules regulating the transactions in spelter which will make it possible for the exchange to stand back of and guarantee such quotations." At present the St. Louis quotations emanate from the Merchants' Exchange, but that body cannot guarantee their accuracy as it does on other commodities.

Consumption of Cyanide in Oregon

Supplementing the figures of the U. S. Geological Survey on cyanide consumption in the United States, given on page 743 of our December issue, we have secured from Oregon operators figures indicating an annual consumption in that state of 104,000 pounds. It

is expected that a new operator will commence work this year and augment the consumption by a small quantity. With the exception of California, the figures given in our December issue and herewith afford a complete statement of cyanide consumption in the gold and silver industries.

Alunite in Utah

Mention has been made previously in these columns of the existence of alunite deposits near Marysvale, Utah, which are potential sources of potash and aluminum. From recent reports emanating from Marysvale, it appears that the development and test of these deposits may be undertaken in the near future. It is reported that a contract has been let for the mining and transportation of 350 tons of this alunite to an eastern point, where experimental work will be done. In the event of a successful method of extraction being developed, a commercial plant will be established in Utah. The Florence Mining Co. is the concern doing this preliminary work.

Copper Leaching and Flotation Processes

Activity in developing and operating copper leaching processes for oxidized ore continues in a marked degree at several western points. At the same time flotation processes are being rapidly developed, and may have a decided effect on the future of leaching. In our last issue, page 63, we noted a patent granted to Mr. Joseph T. Terry, Jr., of San Francisco, California, for the flotation of oxidized ores of copper and other metals, by previous conversion of carbonate or oxide forms into sulphides by means of hydrogen sulphide, and then recovering the mineral by flotation as in the case of original sulphides. This method of "sulphide filming" and mechanical recovery may be found more advantageous from an economic point of view than that of leaching. At least it appears simpler to grind, convert and float ore containing oxidized copper mineral, than it does to handle the same ore by a hydrometallurgical process, with its large volume of circulating solution, incomplete extraction, economic limit of washing out dissolved metal, difficulties of precipitation, fouling of solutions, etc.

The sulphide-filming process admittedly gives a low-grade concentrate, due to the fact that the reaction between the oxidized copper compounds and hydrogen sulphide is so strong that particles of gangue containing even a minute quantity of copper will become converted to sulphide and thus float with the concentrate. It is understood, however, that further improvements in the application of sulphide-filming give promise of affording a method of producing a high-grade concentrate with practically complete extraction. Just what the final effect of this type of process will have on the future of leaching is difficult to forecast, but there is a possibility that progress in leaching may halt to determine the advantages of the new idea.

Chemical Control of Copper Leaching

A number of important analytical operations are involved in the control of copper leaching processes. Some of these are not exact, but give concordant results and afford quick determination to control mill operation. If the same methods are used on a variety of ores, comparative results can be obtained that will be valuable for reference. A solubility test can be made by treating 1 or 2 grams of ore in a beaker with 20 cc. of 5 per cent sulphuric acid (5 deg. Be., or 1.035 sp. gr.), allowing the mixture to stand for about 24 hours. The dissolved copper is filtered and washed from the residue, and determined by electrolysis.

The determination of free acid in the mill lixivium can be made by titrating in the cold a 50 cc. sample with standard sodium carbonate solution (1 cc. = 50 mg. H_2SO_4). The end point may be observed by the use of methyl orange, or the titration can be conducted without an indicator until a slight permanent precipitate appears after shaking. The presence of much manganese will vitiate the results, but with ordinarily clean solutions either method is satisfactory. If extreme accuracy is desired, the solution can be evaporated to dryness on a water bath. The residue is treated with absolute alcohol, filtered and titrated.

Iron will exist in both states of oxidation. Ferric iron is obtained indirectly by difference between total and ferrous iron. To determine ferrous iron, dilute say, 50 cc. of the liquor to about 200 cc., add 10 cc. sulphuric acid and titrate with standard potassium permanganate solution (1 cc. = 10 mg. iron). For total iron, dilute 25 cc. to about 100 cc., add sulphuric acid as before and boil with metallic zinc to precipitate copper and reduce all iron. Complete reduction can be determined by testing with KCNS. Cool and titrate as before, determining total iron. Copper in the mill solution is determined by electrolysis, and from the remaining solution the determinations for manganese, magnesium and lime can be made.

Company Reports

The ninth annual report of the *Consolidated Mining and Smelting Company of Canada, Ltd.*, for the year ended September 30, 1914, shows net profit from operations of $474,012, out of which four dividends aggregating eight per cent, or $464,376, were paid. The properties of the company are reported in good condition. The sum of $482,134 was spent on improvements at the smelter, comprising two Wedge roasters, conveyors and automatic scales for handling material in connection with the roasting plant, three new lead blast furnaces, Cottrell plant for precipitating fume from blast furnace gas, rebuilding three copper blast furnaces, installation of an additional blower having a capacity of 40,000 ft. of air per minute, rebuilding fire protection system, etc.

The additions to the roasting plant were necessitated by changes in the ore supply, demanding more capacity. The Godfrey roasters already in use had a capacity of only 25 tons each per day of Sullivan ore, whereas the two Wedge roasters recently installed have a capacity of from 85 to 95 tons each per day, and cost about 50 cents less per ton to operate, the saving being mainly in fuel. The cost of operating the Huntington-Heberlein pots has been reduced by the introduction of mechanical appliances for hand labor. The addition of a Cottrell precipitating plant was necessitated by losses in blast furnace gases. Since completing this installation, about eight tons per day of lead product is being saved. The rebuilding of furnaces was made necessary by the deterioration of the old ones. Two of the copper furnaces have been enlarged from 300 in. to 420 in. in length, and from 42 in. to 50 in. in width at the tuyeres. The enlarged furnaces show an increase in smelting capacity of from 60 per cent to 80 per cent over the old ones. The changes made at the smelter during the past two years will result in sufficient saving in cost of operation and recovery to pay for themselves within the next two or three years.

The Electric Furnace Products Co., Ltd., of Saude, Norway, has been organized for the production of carbide and other electro-metallurgical products. The probable production is estimated at 60,000 to 80,000 tons annually, to be exported to the United States.

The Non-Ferrous Metal Market

There has been a distinct improvement in the non-ferrous metal market during the last thirty days. Copper and spelter especially have been very strong. Lead is inclined to be weak, with tin about stationary. The advance in prices has been substantial and it is felt that the improvement is warranted and will be maintained.

Copper.—Both domestic and export business has been good and prices seem to be firmly established. Prices have ranged as high as 13¾ cents, and a large business has been transacted at 13½ cents, New York.

Tin.—This market has recovered from a decline in the London market and prices are firm again at about 33¾ cents for January tin.

Lead.—Prices for this metal have fallen due to close competition between independent interests and the largest producer. The American Smelting & Refining Co. finally reduced the price to 3.70, which is the latest available figure. St. Louis market is quoted at 3.50@3.55.

Spelter.—Consumers have been buying heavily and steadily, and the large volume of business has resulted in advancing prices. Export business continues good in high-grade spelters, these brands commanding a premium. The New York price for ordinary grades is 6.02½@6.07½ cents, with St. Louis at 5.85@5.90.

Other Metals.—The aluminium market is quiet, with prices firm at 19@19¼ cents per lb., New York. Antimony is showing more firmness as stocks decrease, and prices for ordinary brands have raised to 14½@15½ cents, with Cookson's at 16½@17 cents. The New York quotation for quicksilver is $50 per flask of 75 lb.; the San Fracisco price is $49.

The Presentation of the John Fritz Medal to John Edson Sweet

On December 2, 1914, the auditorium of the United Engineering Society Building was filled to overflowing with a representative gathering of engineers and their ladies to see the presentation of the "John Fritz Medal" to John Edson Sweet, founder and president of the Straight Line Engine Company, professor of mechanic arts at Cornell University in its early days, the virtual founder of the American Society of Mechanical Engineers, of which he is a past-president and honorary member, and recipient of the degree of Doctor of Engineering from Syracuse University.

Gano Dunn, past-president of the American Institute of Electrical Engineers, presided and was supported on the stage by the members of the board embracing many of the most distinguished engineers in the country.

The manner of Mr. Dunn's presiding was so admirable as to call forth almost universal comment. He said all that was necessary without arrogating to himself the opportunity to make a speech; while his enunciation without being slow and therefore tiresome, was so clear-cut and distinct that every word must have been audible in the farthest reaches of the auditorium.

Dr. James Douglas, past-president of the American Institute of Mining Engineers, made a brief but suggestive address upon the ancient partnership between the miner and engineer, the former being first the dominant partner. He described how through the evolution of his manifold activities the engineer had first reached, and then passed in importance all his competitors in mining and industrial life, but Dr. Douglas pointed out that great as the engineer had become he would never be able to dispense with the miner, on whom he must depend for the materials upon which to practice his art.

Dr. Douglas was succeeded by Dr. W. S. Stratton, director of the United States Bureau of Standards at Washington, whose address consisted largely of a catalog and explanation of the activities of his bureau.

He was followed by Mr. John R. Freeman, past-president of the American Society of Mechanical Engineers, who told the story of the establishment of the "John Fritz Medal," the method of its award, and outlined the notable achievements of Professor Sweet in furthering the mechanic arts, in teaching sane and rational principles of design, and in applying what had been until then only curiosities in the way of scientific measuring instruments, to the construction of commercial machines, with the result of building machinery of a quality of which America at least up to that time was ignorant.

It was a clear, concise statement of facts without direct praise to the recipient, such as every engineer should be, and unfortunately only a few are, able to make.

It may properly be stated here that Professor Sweet has done surely as much, and perhaps more to introduce accurate methods of measurement into industrial life than any other man in America, having designed and made among the very earliest of the straight edges, surface plates, accurate squares, and michrometer calipers ever made in this country.

When he founded the Straight Line Engine Company some thirty years ago he applied these instruments and many others specially designed for the purpose, to the construction of his engine and put it on a plane of workmanship far beyond that of any other engine builder and equal to, if not beyond, the standard of the most accurate machine tools. This workmanship, combined with boldly original designing, resulted in putting his engine in a class by itself.

He did not try to maintain his lead by closing his shop to others and preventing them from following his methods; but, on the contrary, carved in the stone arch over the entrance door, there were the words "VISITORS ALWAYS WELCOME," which he made literally true, and in addition he licensed his rivals to use patented features of his design.

This shortened the period of his engine's pre-eminence but vastly improved the standard of high-speed engine building. Not only has he always offered priceless information freely, he has been blessed with the gift of teaching in its broadest sense, such as few men possess; the gift of putting into simple language the most difficult explanations and in such original and striking form that the hearer can not only understand but can scarcely forget them.

The writer can remember after the lapse of more than twenty years almost the exact language used in making many explanations of difficult points. This is true not only of technical affairs; in matters of ethics an instinctive knowledge of the right has many times within the writer's knowledge, found expression in simple language which seemed to put any but right conduct beyond consideration.

It has sometimes happened, though perhaps not very frequently, that a man had made wonderful achievements as an engineer, but in the minds of those who knew him best had spoiled it all by undue pride in his own accomplishments, denying others just recognition for their help or other defects of character impossible to forget in connection with the man, but this is not such a case. Professor Sweet is less widely known than he might well be in virtue of his great achievements because of his excessive modesty. It is probable that of all the hundreds there gathered John Edson Sweet was the only one who did not think that he deserved the "John Fritz Medal."

On his personal side Professor Sweet has always had a gift pertaining only to character, and never to achievements alone, of attracting to himself, from his earliest years down to the present time, those with whom he had been thrown in contact, and maintaining relations in many cases of positive affection with them, not for short periods, but for life.

It is probably not known to more than a few people that instead of the occasional birthday dinner which has been given to some distinguished men, Professor Sweet has been the recipient of this honor annually for every year except one for the past fourteen years, the one exception being a year when he was out of the country at the time for this annual gathering.

The dinner has been a small one made up of those whom Professor Sweet himself had spoken of as his "boys"; though most of them are now gray and many of them white-haired. The first of these dinners was held in 1901 in response to a suggestion from one of the "boys" that it would probably be a matter of great gratification to "Professor," as he is universally called, to see as many of the "boys" as possible gathered together at one time, his association with them having been scatered over a wide range of time and space, so that while each individual knew the names of many of the others he knew but few of them in person. The plan was carried out in complete secrecy as regards "Professor" at the annual meeting of the American Society of Mechanical Engineers in New York in 1901, since this followed by only a few weeks Professor Sweet's seventieth birthday, and was the easiest occasion on which to get together a large percentage of the "boys."

At the first dinner about forty out of a total of sixty who had been reached were assembled, and the memory of the delight with which "Professor" saw what had been for many years the dream of his life carried out, the foregathering of a large percentage of the "boys" at one time and place, will never leave those who had the privilege of seeing it.

The occasion was made the opportunity for the presentation of a watch with magnificent works, but a case of "Bower-Barffed" iron, suited to the quiet taste of the recipient, and embellished with a tiny bas-relief of the first Straight Line Engine.

This first gathering was so great a success in all particulars that it was voted to make it an annual affair, a plan which has been carried out ever since.

These are perhaps not matters of technical importance but they may help to give to those who do not know in person this year's recipient of the "John Fritz Medal" an idea of his character such as direct description alone could not do. It is doubtful if the receipt of the medal by any other American engineer would have given pleasure and satisfaction to so great a number as has this award. J. E. J., Jr.

A pyrophoric alloy patented by Anton Kratky contains 84 per cent rare earth or cerium, 8 per cent magnesium and 8 per cent zinc or its equivalent in cadmium. The alloy is said to be very suitable for lighting devices working on the strike principle.

The production of nitrate in Chile has been seriously affected by the war, and thousands of people have been forced into idleness. The problem of caring for the unemployed has seriously come up.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in October, 1914, was 60. The total quantity of ore milled during that period was 2,357,695 tons. There were 9854 stamps in operation with an average duty of 8.96 tons per 24 hours. Tube mills in commission numbered 294. The yield for the month was 733,746 fine ounces gold, the largest for the year.

Hearing of the Proposed Amendment of the Patent Laws

On October 8, 1914, Congressman Calvin D. Paige of Massachusetts introduced a bill in Congress (H. R. 19187), proposing an important change in the patent laws in especially two directions, namely, first, that a patent shall be granted only for the *process* of making a drug, medicine, or dyestuffs, and not upon the *product* itself; and, second, that any patent relating to the manufacture of drugs, medicine, or dyes, shall be actually worked in the United States within two years.

A hearing was held on January 13 and 14, 1915, before the Committee on Patents of the House of Representatives, Chairman William A. Oldfield presiding.

Congressman Paige made the opening statement in which he explained that he had introduced his bill for the relief of the textile industry of this country, the intention being to alleviate the dyestuff situation created by the European war and break the world-wide monopoly of Germany in dyestuffs. The bill is not intended to apply to all patents, but simply to the dyestuff industry.

A general discussion followed in which Congressman Herman A. Metz of New York was most prominent in opposing the bill. He denied that the finishing companies and woolen manufacturers were not adequately supplied with dyestuffs. "The dyestuffs are coming in in adequate quantities, and will continue to come in in larger quantities." The prices of dyestuffs to American consumers are higher by 25 per cent than before the war, but only 10 per cent is due to an increase in price of the manufacturer and 15 per cent to the increase in freight rates and insurance rates.

Mr. Metz denied that the compulsory working clause, after it had been introduced in England, had worked satisfactorily. Mr. Metz also emphasized that the Committe on Chemicals and Dyestuffs of the New York section of the American Chemical Society had expressed itself unanimously against a compulsory working clause (see this journal, Vol. XII. p. 754).

Mr. Metz emphasized that "a plant does not make dyestuffs; a patent does not make dyestuffs; it is the material necessary to make them with. Those materials we have not got here, and we will not have them for some years to come. It is an interlocking proposition. . . . The question of patents we have had for years. Manufacturing it is really a question of tariff. There are 900 articles free, and there are only about 5 per cent of articles that are patented."

Mr. Georgii pointed out that the essential features of the manufacture of dyes in Germany are not so much based on patents as on trade secrets.

Mr. William G. Garcelon, attorney at law and secretary of the Arkwright Club of Boston, made a statement in which he said that the difficulty of the New England mills "perhaps goes deeper than the dyestuffs question, because the mills cannot sell their goods." They have bought a year's supply of cotton at somewhere between 13 and 15 cents, and now, when the price has dropped to 6 and 7 cents, the mills find themselves stocked with high-priced cotton and the buyers demanding goods on the basis of 6-cent cotton.

Mr. Garcelon would not now express himself definitely one way or the other as to the desirability of the legislation in question, though he discussed several points. "I am frank to say that I can go to certain men in Massachusetts today who have not discussed this question and I could get them to say, 'Yes, it is a fine thing; put it through; it looks good to me.' On the other hand, I am frank to say, I can spend an hour with them and present some of these things and they would say 'It is a bad thing; do not put it through'!"

Mr. JOHN H. BRICKENSTEIN, of the firm of Byrnes, Townsend and Brickenstein, patent attorneys, of Washington, D. C., emphasized that "this bill is making a fundamental attack on the general principle of the whole law under which patents are granted. It is not only an attack on that principle but it is for the benefit of a certain few, and is class legislation of the rankest kind." Against the proposition to make the bill general, the objection must be raised that this would deprive a patentee of one of his exclusive rights to his invention. In a rather amusing colloquy with Congressman Oscar Callaway of Texas, Mr. Brickenstein went to some lengths to explain that patents are granted in order to induce an inventor to disclose his invention.

"An inventor has got something worth while, and he will not disclose it, and Congress says to him, 'If you will disclose it we will protect you for 17 years,' and that is the inducement for the disclosure, and it has been that disclosure and the patents granted that have enabled the inventor to make money out of his invention, which has so enormously stimulated the manufacturing industry in this country."

Mr. Brickenstein argued that the bill would be in direct opposition to the existing treaty with Germany; further, in proposing to grant patents only on processes, not on products, "we will take away from the chemical manufacturer the most valuable kind of patent he can get. . . . Chemical process patents, as our courts are now constituted, are enormously difficult to sustain. The passage of this bill, with the elimination of product patents, would practically in this country take away every stimulus to the disclosure, which is the thing the law is after, the disclosure of any chemical inventions that are made. Everybody who could would keep them secret."

Mr. Brickenstein quoted from *Metallurgical and Chemical Engineering* (September, 1914) Dr. Hesse's exposition of the economic reasons why not more dyestuffs are made in this country. He emphasized that the way to begin a dyestuff industry is with the coke ovens.

A letter by Dr. BERNHARD C. HESSE, chemical expert of New York, to Mr. Metz was read in which he expressed the opinion that "there is no reason to believe that any good whatever will come from H. R. 19187 were it to be placed bodily on our statute books; on the contrary, all past experience allows of but one conclusion—namely, that H. R. 19187, if enacted into statute, would raise false hopes, and a false sense of security, and would miss fire absolutely."

DR. BAEKELAND'S STATEMENT

The most extensive statement of the hearings was made in the session of January 14 by Dr. L. H. BAEKELAND, of Yonkers, N. Y., president of the Inventors' Guild, past president of the American Electrochemical Society, the American Institute of Chemical Engineers, and The Chemists' Club. "The Paige bill aims at some evils which are supposed to exist in our patent system and which relate to the manufacture of chemicals. It would be useless to deny that certain of those evils exist. We know that certain foreigners take out chemical patents in the United States, not with the idea of working them but with the idea of preventing others from carrying out those patented processes. But such occurrences are relatively rare, and on account of this I think it is wrong to exaggerate any statements as to the extent of that evil.

"The Paige bill aims at suppressing the possibility of taking out a chemical patent without working it. The question is: Are the means proposed by the Paige bill the correct ones, and in suppressing the evil will the remedy not be worse than the evil itself?"

COMPULSORY WORKING CLAUSE

Dr. Baekeland first took up the proposal of the compulsory working of patents and recited how similar clauses have worked in other countries. He first spoke of Belgium. "Belgium has a patent law which provides compulsory working of patents. Belgium has, furthermore, a patent law which forbids the taking out of a patent for medicinal preparations."

"At the same time, Belgium can not boast of a chemical industry similar to that of Germany, neither in importance nor in variety, yet it would be very easy in Belguim to manufacture a large number of chemical products which are now made in Germany. I do not need to dwell on the spirit of industrial enterprise of Belgium. Belgium is a very highly organized industrial country, and in several industries outclasses the Germans—for instance, spinning and weaving industries, some metallurgical industries. But, what is more interesting, Belgium is the very country from which Germany gets the raw materials for the manufacture of aniline dyes.

"There is one detail which many of you probably have overlooked; that is, that when you speak about coal tar, which is the base of the aniline dye industry, any coal tar is not good for that purpose; it needs special coal tars, and it so happens that German coal tar is not so good, while Belgium coal tar is very good; English coal tar is good, too, and yet Belgium prefers to send its valuable coal tar to Germany and let the Germans fuss with it and produce many chemicals from it, which are exported and distributed the whole world over, and the Belgians buy back some of those dyes and chemicals manufactured by the Germans by means of the very raw materials sent there from Belgium." (In reply to a question by Mr. Metz, Dr. Baekeland said that the American coal tar is totally unsuitable for the profitable manufacture of some of those chemical products.)

"The Belgians prefer to weave cloth, spin yarns, make tissues, and to dye them with dyes manufactured in Germany. A few dyes are manufactured in Belgium, but the production of those dyes is a small industry; that is, as far as Belgium is concerned.

"In England a similar condition of affairs exists. England had introduced the compulsory working clause in her patent laws and had great expectations, as we always have before we try an experiment. It so happens that as far as the production of dyes is concerned, England is no better off than the United States. In fact, Mr. Metz forgot to mention the important fact to you that certain special coal-tar dyes are manufactured in the United States to a larger extent than in Germany or any other country in the world. It so happens that the manufacture of those particular dyes suits the special conditions of this country."

In answer to the question by the Chairman as to how the introduction of the compulsory working clause had worked in England, Dr. Baekeland spoke of the effect on a chemical process of his own. "I sold my patents in Europe, but on account of the compulsory working law in England we were compelled to start a special smaller factory in England. The market in England was so restricted that we could not to advantage organize the complete technical, scientific and engineering staffs nor the full equipment which is needed for conducting that particular enterprise in a profitable way with a limited market, and in England there has been every year a steady loss, so that we have to write off from the books every year a considerable sum of money. We are not able to produce in England all the different varieties of that particular product, for the reason that we could not possibly keep up a sufficiently large installation, and the result has been that England could not

be as well supplied with the many varieties of the particular product I am referring to. The question is being debated and will probably be decided in the affirmative that we shall be compelled to stop the manufacturing plant in England entirely. We prefer to forego the British market than to be compelled to work at a loss.

"I know that a similar thing has happened with other manufacturers. After a few years they came to the conclusion that it was cheaper not to take out patents in England after they realized that the market in England was too restricted for a complete and expensive chemical plant and organization. The same kind of logic applies to Canada, where they have also a compulsory working clause, which is further aggravated by the fact that you can not import in that country any goods patented in Canada without losing your patent rights, so that you can not even try the market possibilities before incurring the risk of building a manufacturing establishment. . . .

"The result is that many inventors—and I am one of them—have concluded that it is better not to take out any patents in Canada. Nobody will use your manufacturing process there anyhow; because if some one takes all the risks of starting a manufacturing establishment without patent protection, the next man can do just as much and follow his footsteps without incurring the risk of 'pulling the chestnut out of the fire' in starting an industry on an experimental scale." (In reply to a question on labor cost Dr. Baekeland explained that labor in the chemical industry plays a relatively insignificant part. "Our labor bill is predominantly for high-salaried chemists and engineers, scientific and technical men.")

Dr. Baekeland further pointed out that "in most countries the so-called working clause is an absurd farce. In Belgium and Italy and Spain it is sufficient to advertise in the newspaper that you are trying to give a license or that you are trying to make commercial connections for working your patents: in other countries all that you have to do is once a year to make some kind of a manufacturing operation before witnesses, and have them sign a certified affidavit that certain operations have been gone through as specified, and then you are all right for another year. Of course, that is rather expensive, but rich manufacturers, rich corporations, and rich inventors can afford it; poor inventors can not afford to do it. The result is that you will find that in most of those countries the poor inventors who have barely the means of paying their patent fees are 'frozen out,' while rich patentees are willing to take their chances, and therefore prefer to spend some money, which may look like a large sum of money for a poor inventor, but which for a large establishment is simply charged to general expenses, while they carry out religiously the formalities of the compulsory working clause every year. The result is that this just increases the general expenses of the manufacturing establishment and the consumer pays for it. It is charged under general expenses, like insurance and everything else.

"In England they have tried to be more drastic, and they specify how much of the material shall be produced in England, and by limiting the amount of patented material which can be imported, they stipulate that the patented material has to be manufactured in an adequate or substantial amount in England. It was just on account of this recent change in the patent laws of England, and during the first hesitation which was produced by this amendment to the law, that several American and German manufacturers started building factories in England. But the result has been that in many instances foreign patentees came to the conclusion that their British enterprises did not pay. Now they are willing to take chances, since they realize that after all if anybody takes up a process, of which the patent was allowed to lapse because the operation of that patent was unprofitable, nobody would care to operate it at a loss and they might as well import the product manufactured more profitably in another country."

With respect to Germany and its compulsory working clause Dr. Baekeland said he had made extended inquiries. "Practically without dissent everybody in Germany told me that the compulsory working clause there had proved of no value; and when I asked them, 'Why do you not drop it?' they said, 'for the simple reason that as long as we have this compulsory working clause we can use it as a retaliatory measure, as an act of reciprocity. We can keep it as a "club" over the heads of England, of France, and of all these other countries which are still pressing us with the compulsory working clause, and if you Americans were smarter you would help us do the same thing by introducing a compulsory working clause into your patent laws, with the provision, however, that the citizens of such countries which do not compel Americans to work their patents in their own country would be also exempted from compulsory working of their American patents.' He told me that this was the only reason why they decided to maintain the compulsory working clause in Germany.

"I believe if anybody wants to introduce from that standpoint such a measure in our patent laws as an act of reciprocity he can accomplish considerable good, but in that case this particular bill ought to be worded differently from the Paige bill." (Dr. Baekeland was here asked by the chairman to write out what he considered would do the work.)

THE PROPOSED SUPPRESSION OF PRODUCT PATENTS

As to chemical patents Dr. Baekeland emphasized how little the scope and purpose of chemical patents is understood by people who are not chemists. "In fact, to my great astonishment, I have found more and more that not only ignorant people but so-called educated people do not know what a chemical patent means. They think it is a patent medicine or something of the kind. Few chemical patents, or at least few important chemical patents, relate to pharmaceutical preparations. The scope of chemical patents is far broader, considerably more important from the general standpoint of industrial development and civilization." As examples of chemical inventions of far reaching industrial importance he cited the manufacture of high explosives, the process of making cellulose which gives cheap paper, the manufacture of aluminium, the cyanide process and so on. "Every one of those processes was a purely chemical process. When you begin to seek a difference between chemical and medicinal products, I can not see where to draw the line."

A chemical dyestuff may suddenly become a medicinal preparation. "There is, for instance, a substance which is called phenolphthalein, which is a dye of a red color and because it has such intensive dyeing properties, some wine producers thought it was excellent to use it for giving a peculiar red tint to their wine. They only had to introduce the smallest, infinitesimal amounts in order to obtain that particular red tint; but after they began to sell their wine there was suddenly in the whole district an epidemic of diarrhœa. By sheer accident they had found that the chemical which up until now had only been used for coloring purposes was a most efficient purgative."

"Chemists labor under great difficulties with their chemical patents. If we have a good patent we are continuously exposed to infringers, and the worst thing is most of the time we can not catch the infringers. As I have said, chemical processes require very few workmen. More than one chemical process is operated with

a single man, and often that man can produce 10 tons as easy as he can 10 lb.; in fact, with proper equipment it is much easier to produce 10-ton than 10-lb. lots for the reason that some of these industries can not be worked profitably on a small scale.

"Last year about this time I was spending about four weeks of my sweet life 'suing' one of the infringers of my patents, and the trouble was that it was very difficult, almost impossible, to establish infringement, because that man, who was a rich manufacturer, made the whole preparation himself; he did not allow a single workman to be present. He testified in court to that effect. We wanted to know what the raw materials were which he used. In Germany it would have been easy enough; in France it would have been easy enough; and in England it would have been easy enough, because the court would have appointed a confidential expert, bound to secrecy, to go into his factory and examine what he was using there. But our rules of evidence here in the United States will not allow this. So we had to establish what raw materials he was using, and therefore the judge directed him to bring before the court his books and invoices and the receipts, and the defendant simply said, 'I have no invoices, I have no records as to my purchases, and I burn all my receipted bills,' and there we stuck. This is not an isolated case. I could take up your time by giving you several more similar cases. . . . I am still waiting for the decision. I have waited a year now. The lawsuit cost me many, many times more than any damages I ever might be able to collect.

"Therefore when a chemist takes out a patent he first tries to see whether he can not obtain a product claim; if he can obtain a product claim, then it becomes easier for establishing infringements, and that is so true that the patent pirate will readily find some way to infringe a chemical patent which does not have a product claim. In Germany they allow no product claims for chemicals, but inventors there do not need them. We would be perfectly glad to have product claims suppressed, done away with, if we had a different and more efficient court procedure.

"It is not a question of patent law, it is a question of court procedure, it is a question of rules of court and broad interpretation of the claims of the patent; unless you can give us those improved rules of court procedure —and these are mighty difficult to introduce in the country where our very Constitution starts from another standpoint, where the rules of evidence are based on another kind of logic than that which impregnates the whole German code and the method of administering justice. If you suppress to us, gentlemen, our product claims you might just as well suppress all chemical patents. Our chemical patents do not amount to a large proportion anyhow. As far as I recollect, they only amount to about 1 per cent of all the patents taken out in the United States.

"But if you suppress a product claim in chemical patents why do you not apply the same rule for mechanical patents? Most mechanical patents are practically product claims. Why should you single out chemical patents? If a man infringes a mechanical patent you can easily detect the infringement, you do not need any detectives nor special chemical knowledge. We tried to use detectives once in the case of an infringer. We sent him to the infringer's factory and tried to get a small amount of the raw material to establish the infringement. The value of the material that man took amounted perhaps to 2 cents. He got arrested; he was indicted for larceny and put in jail. In the meantime they keep on infringing my patents. Why? Because when you sue on a process claim you generally can not get at the infringer except in certain cases. You could not break into one of those chemical establishments with dynamite; most of them use secret processes, and that is something which evidently Mr. Paige overlooked when he drafted the bill. I am sure he does not want to harm chemical industries, because his very bill aims at supporting chemical industries. He wants to back them up; he wants to make them stronger in the matter of competition with foreigners. He is perfectly justified in trying to do this, but unfortunately in trying to accomplish that result he is going to do incalculably more harm than the good he is trying to accomplish.

"I have nothing whatever to do with dyes or dyestuffs. I am not interested in that. I shall not talk of the commercial side of it, but I know that the situation is very similar to the situation in the manufacture of other chemicals with which I am better acquainted. The whole chemical industry here in the United States does not have to blush at all when compared with that of other countries. It is, in fact, remarkable that this country should have done as well in chemical industry as history proves. The world's electrochemical industry has been mostly developed by pioneer inventors here in the United States, and this division of chemical industry has taken tremendous proportions here in comparison with that of Germany, which has specialized more in the manufacture of dyestuffs; in both countries these specialties have developed in accordance with the natural opportunities offered by each of them."

THE CHEMICAL INDUSTRY AND THE TARIFF

"To give you some relative values, the United States is making one particular product which is called oleomargarine. The exportation of oleomargarine from this country to Germany was larger than the whole importation of aniline dyes from Germany. There are some other conditions which have produced quite awkward situations here in this country. Since our tariff law became a political issue instead of a plain business issue, and since the tariff has been changed and changed and changed over again, chemical manufacturers do not know where they stand.

"I will give you one concrete example, because I have been identified with it. I have just now before me a proposition which involves the construction of a manufacturing establishment of several million dollars. It so happens that right here in the United States a process has been developed for making a product, which I do not want to mention now by its real name but which I shall call B. In order to manufacture that product you need another product which is called A, which is the raw material for B. Now, this product A is manufactured in Germany by patented processes, and the corresponding patents exist also in the United States, but the patents are not worked here. You can not manufacture B profitably unless you get A cheap enough, but it so happens that some company here in the United States had a little bit of a factory in which A was manufactured by means of an inferior and absolutely obsolete process; it had succeeded in influencing Congress to put a prohibitory tariff on A, to the point of protecting it by 50 per cent of the selling price of A. In other terms, when Canadians or Englishmen pay, say, 10 cents for the product you have to pay 15 cents in the United States.

"It happens that that small American concern does not produce 10 per cent of the total consumption of that product A in this country. To make matters worse, the product B—which could now be made by means of an American invention, and which is at the point of being manufactured on a large scale, except for these particular difficulties—this product B is one of the chemicals which has been put on the free list. The

manufacturers of B, with our lax patent laws here, under which it is easy enough to infringe a chemical patent, might be disposed to take chances and infringe the process patents of the product A and manufacture the product A according to the German patented methods. Indeed the American patent disclosed the manufacture of the product A, but it is an enormously different thing—Mr. Metz is a manufacturer and knows that—to manufacture a product, and to manufacture it profitably. In other words, the yield of 10 per cent, more or less, or a slightly better quality, will make a process a losing business or a paying business. Now if any of these people here, in order to manufacture the product B, try to infringe the patent A, or even if the German patentees of the American patent A gave them that patent A for nothing, but would not communicate them their long experience in manufacturing, so as to obtain maximum profitable yields, the use of that process would be unprofitable from a commercial standpoint.

"In the meantime the result of this situation is that very probably this new American process—the process patented in America for producing this product B—will be compelled to go and locate in Canada in order to get cheap A imported from Germany into a country where A comes in free of duty, and after having manufactured B in Canada, it will be more profitable to ship this product to the United States, because B enters duty free in the United States although the raw material A from which B is made is loaded with an enormous duty.

"This is one of the many examples I could mention of the absurd conditions with which some of our chemical industries have to contend in this country. It is not only a question of chemical patents, but also a question of tariff and a question of raw materials. And then there is another matter which must not be slighted, although it has not yet been mentioned here. The matter to which I am about to refer should not be exaggerated; but it exists nevertheless. I know of instances where German manufacturers have said, 'If you manufacture such or such a product in your country we will make it impossible for you, because we have an establishment here which is so big and so complete that we can supply the demand of the whole world. We can not afford to manufacture profitably on a small scale, and therefore must keep our full units working; and we will undersell you in the United States, which will drive you out of business. In the meantime we will raise prices in other countries where we have no competition, so as to compensate for any loss we sustain in underselling you in the United States.' "

Questioned as to the chemical industries of this country and England, Dr. Baekeland thought that unbiased Englishmen themselves will acknowledge that of late we have gone ahead considerably farther than they have done. But "if we are speaking about English inferiority in chemical manufacturing, this is only relatively true. We cannot say that England is not still a very superior and important chemical manufacturing nation. And when it comes to some of the industries in which they are masters we must recognize that even Germany is second, and in whatever thing those countries have specialized it has been according to the lines of least resistance. The English textile industries and the English metal industries are so important in England that she can well afford to neglect some of her chemical dye industries or other mechanical industries, about the same way as in this country for a number of years we quite naturally gave far more importance to the industries of mining, transportation, and the mechanical industries generally. There was no need of chemical industries. It is not so many years ago that the manufacture of sulphuric acid on a large scale was practically impossible in this country. Why? Because there was no market for it. We are now, I believe, the largest sulphuric acid producing country in the world. I do not think there are any countries which produce more sulphuric acid than the United States. It required natural opportunities—the discovery of the phosphates to make superphosphates, the dynamite and explosives industry, the refining of petroleum in order to create a market for sulphuric acid.

"It is the same thing with the dye industries. The dye industries, unfortunately, are broken up into many little side branches, relatively small matters which in this country would by themselves be almost beneath the dignity of a man of enterprise to bother with. In Germany they can do it collectively, and why can they do it collectively? Because they can do a good many things there which would not be tolerated by the laws of this country. You all know—it has been mentioned here—that those German aniline industries make up an immense trust. They have agreements as to price, as to markets, and as to the restrictions of sale and restriction of production; and if there are any new patents, if one factory buys one patent the other can use that patent." . . .

"I visited one of those works. They do not look like factories; they look like well-organized towns. They treated me with unusual consideration, because they showed me what they very seldom do to visitors—several departments of their plants, and, in fact, some departments I was enabled to study for several days in succession. They took me in an automobile to drive around the plant, and it required the better part of the afternoon to run through the many streets of their plant and to visit hastily each of the many buildings." . . .

"There is another matter I want to call your attention to. The American promoter ordinarily wants to get rich quickly. He does not want to trust to any industry which requires slow but healthy development. A couple of years ago I spoke to the director of one of those large (German) enterprises, and he seemed pretty well imbued with the idea of the importance and development of his plant, and I asked him what dividends they paid. 'Oh,' he said, 'we are paying as much as 28 or 30 per cent dividends.' 'Well,' I said, 'that is a lot, but what does it amount to in dollars and cents?' Then he told me what it amounted to, and I was amazed at how little it was relatively speaking. I said, 'Have you any water in your capital stock?' 'No; that is not allowed in Germany.' 'Have you amortized any of your buildings?' 'Oh,' he replied, 'quite some.' I said, 'Then do you mean to say that your capital stock is considerably smaller than your real assets?' 'Yes,' he said. 'When did you start?' 'In 1862.' 'Do you mean to say,' I asked him, 'that after 50 years, that is all you have to show?' 'Yes,' he said; 'we are entirely satisfied.'

"Now, in America any third-rate industrial enterprise—badly managed as some of them are—at the end of 50 years would be ashamed to declare a dividend of that kind, if you calculate it on unwatered stock; but those people are satisfied with small profits. I know it, and I know furthermore—and probably Mr. Metz knows it, because he is a manufacturer, too—that some of their departments work at considerable losses. A large number of those departments do not pay at all. Some other departments pay better, and they equalize or offset the losses, and they seem to be satisfied with the ultimate result. But if you take those dividends and compare them with the dividends of some American concerns on the basis of their watered stock, their returns are disappointingly small from the American point of view.

"Gentlemen, there is one thing that you could do. I

have spoken of it to your chairman, and I wish to take the liberty of repeating it. If you really want to render any service to the industrial development of this country, and more particularly to its chemical industries; if you aim at any change in our patent laws, please arrange matters in such a way that patent litigation becomes more direct, less complicated, and less expensive. The way patent protection is now administered in our country is a gross absurdity, and no safeguard for chemical industries based on improvements and pioneering enterprises."

Mr. Metz said that the dyestuff imports into the United States are about $1,000,000 a month; $12,000,000 a year will cover all the importations of dyestuffs and raw materials for dyestuffs. "I want to emphasize that point as to the relatively small value of these things in proportion to the size of the industry into which they go—cotton, silk, wool, paper, typewriter ribbons. There is scarcely an industry that is not affected. Even the ink for the red headlines in the newspapers—those have had to be discontinued. The total new profit to the manufacturer of these materials (at a normal average profit of 25 per cent) would be at the maximum $250,000 a month, as compared with the entire business of the United States. If the German manufacturers shut down entirely they would lose almost nothing, but we would lose hundreds of millions of dollars for the lack of stuff to keep our mills going. That is why the Germans are not anxious to-day to export a single pound; it is a favor to us. They want to keep these things out of England. That is their business, if they want to do it. They do not want to let a single pound of these materials go to England or France or any manufacturing country, and they are afraid that if they give us any more we will send it to those countries. The trade in those products is a very small factor with Germany, and anything that will tend to prevent the importation of those things at this time will injure us to an extent that will far more than offset any benefit we will get."

Dr. Baekeland in concluding said: "I know that the importation of coal-tar dyes into this country—although it amounts to $12,000,000 a year—is a small item compared with a lot of other items of which we have not spoken at all. For instance, I know that New York City consumes in one year eggs of a value two and one-half times as great as the value of all the aniline dyes imported in one year into this country. Any man who could make a law to increase the size of eggs by one gram would make himself infinitely more useful to his country than a man who could increase the production of those aniline dyes. In fact, the trade in sheep manure for tanning and other purposes is about equivalent in value to the value of aniline dyes imported into this country."

The hearing was then adjourned.

The Engineering Foundation was inaugurated with appropriate exercises in the United Engineering Building, New York, on the evening of January 27, 1915, under the auspices of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, and the American Society of Civil Engineers. A gift of $200,000 by Ambrose Swasey, designer and builder of the Lick, Yerkes and U. S. Naval Observatory telescopes, and an engineer, scientist and astronomer of high distinction, forms the basis of the Foundation. Mr. Swasey is a member of the firm of Warner & Swasey, machine tool builders, of Cleveland, Ohio, and a past president of the American Society of Mechanical Engineers. The principal speech of the inauguration exercises was made by Dr. Henry S. Pritchett. The fund will be used chiefly for research work.

Dinner to Frederick G. Cottrell

A dinner in honor of Dr. Frederick G. Cottrell was held on the evening of January 15 at the Plaza Hotel in New York City, under the auspices of the American Institute of Mining Engineers, the American Electrochemical Society, and the Mining and Metallurgical Society of America. The occasion was graced by the presence of many ladies.

The purpose of the dinner was to honor Dr. Cottrell for the service rendered by him to the advancement of science, as stated in the following minute, adopted on the same day at the annual meeting of the Research Corporation and distributed appropriately in printed form at the dinner:

"In 1911 Frederick G. Cottrell, B.S., Ph.D., offered to transfer to the Smithsonian Institution substantially all his rights in his inventions and patents covering the processes known as the electrical precipitation of suspended particles in order that the profits resulting from the application of the patents, already well assured, might be applied to the advancement of scientific research and investigation. Naturally this proposition was at once recognized as both generous in spirit and highly original in conception. It was Dr. Cottrell's ideal to render discovery already made the mother of new discovery, and thus contribute to the scientific and technical development of the industrial arts.

FREDERICK G. COTTRELL

"This far sighted and patriotic conception found its realization through the Research Corporation which for administrative reasons was substituted for the Smithsonian Institution as the custodian of Dr. Cottrell's endowment. The objects of the Research Corporation as stated in its charter are: 'To provide means for the advancement and extension of technical and scientific investigation, research and experimentation by contributing the net earnings of the corporation, over and above such sum or sums as may be reserved or retained and held as an endowment fund or working capital, to the Smithsonian Institution, and such other scientific and educational institutions and societies as the Board of Directors may from time to time select in order to enable such institutions and societies to conduct such investigations, research and experimentation.'

"Organized in 1912 as a stock corporation but precluded by its charter from paying dividends and capitalized by a group of gentlemen desirous of furthering Dr. Cottrell's objects, without personal profit, the Research Corporation undertook and successfully accomplished the installation of the Cottrell processes in various industries throughout the country, with the result that in two years' operation its surplus has provided the capital of twenty thousand dollars required by its charter, and a fund of over one hundred thousand dollars for scientific research.

"The accomplishment of this remarkable result, which both justifies Dr. Cottrell's expectations and realizes his hopes, is due to his generosity and foresight, and the

PHOTOGRAPH TAKEN AT DINNER TO DR. FREDERICK G. COTTRELL

Directors of the Research Corporation take this occasion to express to Dr. Cottrell their appreciation of his contribution to scientific achievement and to the advancement of science, and tender him their cordial congratulations and sincere thanks for the public service which he has rendered."

Mr. SIDNEY J. JENNINGS presided at the dinner. In his introductory remarks he spoke of mining as the basis of civilization and of Dr. Cottrell as a very practical idealist. He proposed a toast to Mrs. F. G. Cottrell, who had been compelled to stay in California and could not witness the tribute of esteem and affection paid to her husband.

Dr. CHARLES D. WOLCOTT, director of the Smithsonian Institution, spoke for the Research Corporation. He related how Dr. Holmes had brought Dr. Cottrell to him and how the organization of the Research Corporation finally resulted. He spoke of the many practical problems which are being taken up or are to be taken up by the Research Corporation, and of Dr. Cottrell's idealism.

Mr. WILLIAM L. SAUNDERS then spoke for the American Institute of Mining Engineers. He said his experience with inventors had been as extensive as it had been expensive. One of the directors of the Research Corporation had told him that the Cottrell patent was worth one million dollars. "This is not at all an unfamiliar statement about a patent to me, though the novelty of it is that heretofore I have heard it only from the inventor. An inventor with a patent, whether it relates to a clothes pin or a submarine, invariably rates its value at one million." Mr. Saunders related forcibly a wonderful story of a dynamite inventor with a patent alleged to be worth a million. The story was fearsome, but had a happy ending. Mr. Saunders concluded:

"But the controlling thought with all of us to-night—the impulse which has drawn us together—is not that we wish to do honor to a great inventor, but to the man. Ours is not a compliment to the brain, but to the heart. That which we so regard, that to which we pay the homage of our admiration and cheers is that one of our kind should be so unselfish as to dedicate this valuable product of his brain to the public good. In doing this he has not only rendered a great service to mankind, but he has set a wholesome example to present and future generations.

"The governor of a western state, who was also a member of the board of directors of a railroad company, told me the following story: He was presiding over the annual meeting of the directors in a western town when a man opened the door of the room and after politely apologizing for the intrusion asked for a few moments' attention that he might explain his plan by which a large sum of money would annually be saved to the railroad company. The first impulse was to put him out, but he held his ground by the statement that as the directors were there for the purpose of saving money for the company, and he stood ready to help them, they should at least let him explain his business. He then said that he had a patent oil for railroad use, the virtues of which he was diligently expounding when the superintendent entered the room in response to a bell call and was ordered to give the patent oil a trial.

"On the year following, these directors met at the same place and recalling the incident the chairman asked the superintendent what was the result of the trial of the patent oil. 'All right,' said the superintendent. 'It is a satisfactory lubricant.' 'Well, I'm glad to hear that,' said the governor; 'the interruption at our meeting last year was a good thing after all; that fellow must have a valuable patent.' 'Governor,' the superintendent replied, 'the value of that patent *is that man.*'

"And so it is in this case, for the economic worth of Professor Cottrell's invention, as high as we know it to be, cannot equal that real value of the patent which is that man. The man whom we so gladly and so unanimously honor this evening is deserving of our highest esteem, for 'hearing ofttimes the still, sad music of humanity,' he is built of such stuff, that,

> "Too high for common selfishness, he could
> At times resign his own for other's good."

Mr. F. AUSTIN LIDBURY followed, speaking for the American Electrochemical Society. He gave reminiscences of the time when he worked alongside Dr. Cottrell at Ostwald's laboratory in Leipzig, "a pleasure which those who shared it will not easily forget."

"Added to those personal qualities which have since won him a nation-wide circle of friends and admirers, we had the advantage of associating with one whose bold and brilliant ideas were only equalled by his ingenuity in devising and executing experiments to test those ideas. He was the most brilliant and original experimenter that I had ever met, and he used to startle us every day or two by producing some new marvel of experimental ingenuity. If he will permit me to say so, I must confess that if the first experiment did not work, it was rarely followed by a second one; but this was no doubt attributable to the fact that he came to us fresh from Van't Hoff's laboratory, where one was held pretty closely down to the determination of vapor tensions and solubilities; no doubt very excellent training, but rather calculated to arouse unruly thoughts in an ardent mind.

"I am asked to speak of Dr. Cottrell's work on electrostatic precipitation. Of the results and far-reaching importance of that work it would be presumptuous on my part to speak to this audience. Nor am I capable of describing adequately the quality of the work itself, or its importance. There are two points to which I would direct your attention.

The first is, that when Dr. Cottrell undertook his investigations the prospects were sufficiently discouraging.

"Electrostatic precipitation of solid particles from gases was no new idea; in particular, it had been experimented with by a famous English physicist, who had, however, not even succeeded in dispelling the fog in his own quadrangle. It did not look either to a scientist or to an engineer exactly the kind of thing that one calls 'practical.' Companies to whom the removal of noxious fumes from gases was a vital matter were not inclined to give the idea when presented to them very much consideration; it was altogether too good to be true; and while money might easily have been found for a small improvement which might look as though it would save a few thousand dollars a year in some detail of their properties, this was altogether too vital and too important a matter to spend money on.

"Under these circumstances, Dr. Cottrell simply went and did it. That is all there is to say in this connection.

"The second point is one which particularly concerns the electrochemist. At this moment, when the revolutionary electrochemical activities of the last decade but one have settled down into a kind of steady development, Dr. Cottrell's success comes as an inspiration to the electrochemist. It indicates to him that the large successes of electrochemistry in the future, the untilled field, are to be sought among the byways and hedges of that bastard technical science.

"But we have met to-night to recognize also Dr. Cottrell's eminent services as an experimentalist in social science. That he so regards himself is abundantly clear from the very interesting paper on the Research Corporation which he presented at the last International Congress of Applied Chemistry. I know few more interesting papers than this, and not its least interest lies in the fact that it is to a great extent a human document. No one, I think, can read this paper without being impressed by the extent to which it reveals that modesty which is one of Dr. Cottrell's chief characteristics.

"Now the particular branch of social science in which Dr. Cottrell has interested himself is that which embodies the relations between the universities and the technical industries. I doubt whether any more fruitful subject for discussion than this has been before scientific people in the last few years. One is reminded of the old Scotchman who was visited by his minister when he was lying on his death bed. 'Sandy,' the minister said, 'shall I read ye a little from the good book?' 'Nay, nay, meenister,' said Sandy, 'sit ye down and let's argue a wie.' Certainly there has been enough argument on this question. Most diverse positions have been assumed; the head of one of the largest research laboratories in this country has been bold enough to state that the time has now arrived when the universities must yield research to large technical industrial organizations, just as centuries ago the church yielded research to the universities. My friend's boldness was, however, tempered with discretion, as he published his article at a time when those who might be expected to be interested in combative issues were taking their vacations.

"Dr. Cottrell stands emphatically on the other side of the question, and his notable contribution is that while, with practically one other exception, the parties to the discussion have confined themselves to discussing, he has gone at the matter in an experimental way. And not only so; experimental research is expensive; and Dr. Cottrell has put at the service of the experimental work on this social question what would have been a most munificent gift from any man on earth; and what, coming from one who is a poor man, is only to be described as unparalleled. Only a scientist in the truest and rarest sense of the word would be capable of such generosity or such self-sacrifice. He has made an indescribable sacrifice in order to try out on an enormous scale the social idea.

"It only remains for me now to wish the Research Corporation every success. Its responsibility is commensurate with the generosity of Dr. Cottrell's gift. It will not find other Cottrells—they do not grow on every bush."

Mr. WALTER RENTON INGALLS spoke for the Mining and Metallurgical Society of America. He mentioned that Dr. Cottrell's official title is that of chief physical-chemist of the U. S. Bureau of Mines.

"If any here present this evening may not happen to know just what a physical chemist is, they need experience no mortification or entertain any notion that their early education was neglected. The physical chemist is, indeed, a rare bird of a new species. Those of us who possess sheepskins dated in the early eighties and in the middle eighties, pursued courses in chemistry and courses in physics, but at that time it had not occurred to anybody that we ought to study the two together. This did not happen until later, and for the reason that the older chemists and metallurgists were not taught the rudiments in the right way they have always been at a disadvantage compared with those of the younger generations, no matter how seriously they have tried to correct the deficiency.

"We are very much like a coachman who was converted into a chauffeur. In the early days of the automobile the chauffeurs as a class possessed a very bad reputation, which no doubt they richly deserved. A certain gentleman, desiring to avoid the evils of grafting, joy-riding, etc., conceived the idea of making a chauffeur out of his honest, reliable and intelligent coachman, and for that purpose sent him to an automobile school of instruction. After three months or so, James returned proudly exhibiting his diploma. 'Yes, sir,' said he, 'I have learned all about the automobile. I know how to put in the gasoline and how to put in the oil. I know how to adjust the carbureter and how to clean the spark plugs, and how to scrape the carbon from the cylinders.' Then waxing confidential, he added, 'Yes, sir, I know all about the automobile engine, but there is one thing I have never been able quite to get into my head, and that is, what makes the blame thing go?'

"Many of us are in the same position with respect to chemical reactions and metallurgical processes in the light of modern theory. We have learned how to pull some of the levers and press some of the buttons, and make things go, but why they go we do not always understand as well as we ought to. We are apt to be strong upon the means how, but weak about the reasons why. Therefore, we sit at the feet of the masters of physical chemistry, among whom is Dr. Cottrell—the modern science in which is wrapped the whole future of metallurgy.

"Now, even before physical chemistry became a science we smelters of an olden time were having our experiences with the gentle art of smoke farming. We were all quite familiar with the agriculturist of our neighborhood who, from time to time, used to call at our works and complain that our sulphur smoke had damaged some especially promising field of corn; or that old Dobbin had developed a spavin, which was probably due to our sulphur smoke; or that the chickens had fallen sick of the pip, for which our sulphur smoke again was to blame. We used to sympathize with our bucolic friend, and wonder whether $50 might compensate for damages, assuage injured feelings, etc. Generally, they allowed that it would, and disappeared for six months, a year, or whatever time they considered to be a proper interval between contributions.

"But as our smelting works became larger and more profitable, so did the avarice and aspirations of the smoke farmers increase, until at length their demands became so onerous that no smelter could agree to them and hope to continue solvent. The consequences were suits for damages, court injunctions, and the development of smelters' smoke as one of the great metallurgical questions of the day, engaging the attention of scientists all over the world. Among these was Dr. Cottrell.

"Dr. Cottrell was acquainted with the experiments of a distinguished British scientist. to whom Mr. Lidbury has already referred, for the settling of London fogs by electrical means. Those experiments had, however, resulted in nothing useful, and the idea of electrical precipitation had been generally dismissed as fruitless. But not so by Cottrell. It was on the point of my tongue to say that Cottrell was from Missouri, but I have happened to remember that in fact he is from California, and anyhow I have never taken much stock in the quality commonly ascribed to Missourians of sticking fast to the idea that seeing is believing. Tell a Missourian that in the firmament above us there are three trillion, several billions, millions and thousands and three hundred and sixty-seven stars and he will believe you without question, just as will a Hoosier or a Yankee. But show a Missourian a place marked 'wet paint' and he will immediately try it with his finger. In fact, human nature is about the same everywhere.

"Well, anyway, Dr. Cottrell prosecuted his investigations, made his inventions, and proved his theory to be correct, and in a surprisingly short period of time we have seen his process attain great importance in our metallurgical industry. And, not only in that, but also has it found applications in other industries. Dr. Walcott has mentioned some of these. It is used for allaying the troublesome dust in cement works. It is used in the preparation of certain powdered foods, especially powdered milk and powdered eggs. It is possible that some of the delicious confections that we have eaten here this evening were prepared by the baker of this hotel with the aid of Cottrell powdered eggs. If not, I submit that the dinner committee should have seen to it. Surely, there is no one here who would not have taken such a chance—once.

"I understand that Dr. Cottrell, not satisfied with the

accomplishments that already are remarkable, is contemplating other Romes to conquer. I believe that he entertains serious ideas of abolisning the smoke of Pittsburgh. If he succeeds in doing that, I do not venture to prophesy the size of the monument that Pittsburghers will erect to him at the junction of the Allegheny and Monongahela rivers.

"Professor Cottrell munificently gave away his process in the interest of science. Mr. Saunders has told us that this process, even in its kindergarten days, is considered to be worth a million dollars. There are not many men who would give away anything worth a million dollars. But we know that Professor Cottrell, besides being a genial and generous gentleman, is a good deal of a philosopher. The path of the inventor, even of the successful inventor, is seldom a smooth one. It may be that Professor Cottrell's philosophy taught him that it is better to be honored and healthy than worried and wealthy. We have tried this evening to show him somewhat of the esteem that we have for him."

The health of Dr. Cottrell was then proposed.

Dr. F. G. Cottrell gave a very fine personal touch to his speech by making the co-operation given to him by others the keynote of his remarks. He insisted that his colleagues in the old Western and International

FROM LEFT TO RIGHT: STANDING, E. O'NEILL, F. G. COTTRELL; SEATED, E. S. HELLER, H. E. MILLER

Precipitation Company should be named with him as co-donors of the patents to the Research Corporation. The first to assist him had been Dr. Harry East Miller, to whose private laboratory in San Francisco the experimental work had been transferred at an early date after it had been started at the University of California in Berkeley on a small scale. The earthquake and fire of 1906 finished this early work. Then Mr. E. F. Heller, a lawyer and business man of San Francisco stepped in, and Professor Edmond O'Neill of the College of Chemistry, of the University of California, became the fourth member of the coterie which carried on the pioneer work for five years until it was turned over to the Research Corporation.

Dr. Cottrell spoke of the help extended to him by Dr. Holmes, Dean Goetze, and others, of the late Dr. Duncan's idealism which resulted in the Mellon Institute for Industrial Research in Pittsburgh, of the international character of scientific organization, and finally paid a quiet and beautiful tribute to the help he had received in all his work from his wife, who had remained in the little bungalow in California while he had gone East on this trip. "You don't know a man until you know his wife."

Annual Report of the Bureau of Mines

In the fourth annual report of Dr. Joseph A. Holmes, director of the federal Bureau of Mines, he presents a summary of the work of the Bureau during the last fiscal year ended June 30, 1914, and discusses some of its needs. An interesting tabulation is made showing the country's relation to the two great basic industries, mining and agriculture, and the federal support given each. The salient facts are that agriculture shows an annual value of products $10,500,000,000 as against $4,600,000,000 for mining; but mining contributes 60 per cent of the freight tonnage of the country as against 22 per cent for agriculture. On the other hand, agriculture receives annually from the government for education, experiment stations and general research $27,970,000, as against $1,967,000. Agriculture is aided by 52 experiment stations for which $1,550,000 is appropriated, while mining receives no appropriation for such work. Bearing on the latter point, and in supporting the idea of mining experiment stations, the Director says:

"Owing to the magnitude of the country, the distances between the widely distributed mineral regions, and the marked differences not only in the nature of the mineral resources of this country, but also in the conditions under which they must be developed, it does not appear to be practicable to conduct efficiently at any one central point researches concerning all of these mineral resources. In addition to one or more central control laboratories, it is important that there should be established in a number of the more important mineral regions of the country local mining experiment stations at which researches may be conducted in keeping with the nature, mode of occurrence, and the development of these resources.

"There should be not less than 10, and probably need not be more than 15, such stations established, the larger number of which should be located in the public-land States west of the Mississippi River. These 15 mining experiment stations will do for the mining industry in this country a work comparable in importance to the work which is being done in behalf of agricultural advancement by the 52 agricultural experiment stations, for the maintenance of which Congress appropriates annually more than one and one-half million dollars, or $30,000 for each station.

"It is expected that the work of each of these mining experiment stations will be supplemented through appropriations made by each of the mining States in which such stations are to be located, and it is further expected that the appropriations made by the States will provide for such portion of the investigations as are local in their character and importance, whereas the investigations provided for out of the appropriations made by the Federal Government will be of a general or national character and importance.

"It is proposed that the establishment of these stations should be provided for through the enactment of special legislation which is now pending before both branches of Congress (H. R. 15869 and S. 5588). The importance of this legislation to the mining industry is such that it can hardly fail of enactment, and with its enactment the bureau will be able to take up and carry to successful completion researches which cannot fail to be widely useful in the upbuilding of the industry."

Leaching of Copper Ores and Electrolytic Precipitation was the subject of a spirited discussion, opened by a paper by Dr. L. D. Ricketts, at a joint meeting of the New York Sections of the American Institute of Mining Engineers and the American Electrochemical Society on January 6. A report is reserved for our next issue.

Handling Iron and Cinder at the Blast Furnace

BY J. E. JOHNSON, JR.

(*Concluded from page* 50)

Handling the Slag

When the blast furnace had its beginning it is almost certain that the slag was handled as clinker or ashes, and this point of view survived until very recent times in the crane-operated shovel, fork, etc., which I have described in a previous article as adjuncts to charcoal furnaces in the seventies and which were used to clean out and "work down" the furnace very much as we find it necessary to do with the average domestic heater to-day. The difficulties of this method of operation a growing knowledge of the use of flux, and the use of the

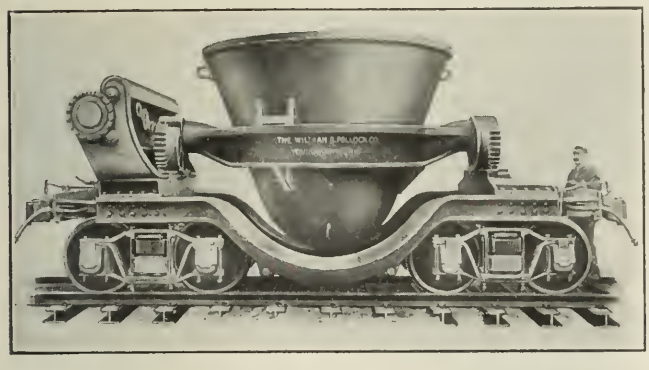


FIG. 15—POLLOCK CINDER LADLE

hot blast with its correspondingly higher hearth temperatures brought the possibility of discharging the slag in the liquid condition and this practice became general though not universal in the early part of the last half of the nineteenth century.

The slag was probably allowed to run out from the furnace with the iron, and after being skimmed off as previously described, was run off to a short distance into puddles in which it was allowed to cool. Slag being very brittle when cold is easily broken up by hand and was disposed of with carts or any convenient means, being simply loaded from the ground into the conveyance with shovels or forks. Carts dumped it into holes or low places, and sufficient of these were commonly found near the plant to take care of the slag output for many years.

Survivals of this method are in use even down to the present time, though they have now become rather rare. When mineral coal was substituted for charcoal as fuel, the quantity of slag produced per ton of iron increased to some extent, but probably not nearly in the ratio which the average volume of charcoal slag bears to that of coke slag per ton of iron produced to-day for the reason that in the early days of mineral fuel it was almost impossible to carry as much lime in proportion to the silica of the charge as we now know how to handle successfully. But even though the difference was not so great it was still very considerable and helped to bring about a change in the method of handling, because with small outputs of iron, and small ratios of cinder per ton of iron, the volume of this material to be disposed of was so slight that no highly organized methods were used for disposing of it.

But with the increase in volume of slag, and also the great increase in tonnage of iron, the importance of slag disposal grew even more rapidly than the question of handling the pig iron output, and a vast number of methods have been devised and practiced in trying to handle it with maximum economy.

A comprehensive search would be required to obtain a reasonably complete list of the methods which have been used on an industrial scale in the past, but as only a few of them have survived this is not needed, a description of a few of the most commonly used will suffice.

The first important development was the choice of a definite dumping place, chosen with the idea of affording room for slag disposal within a limited area for a long term of years and railroad transportation for delivering the slag to it.

Probably the earliest improvement was to run the cinder into long parallel runners roughly made up in coke brise so that the size of the individual bodies of cinder is limited, because while this material is very brittle as compared with iron, if it is cast into puddles of several feet across, and a foot or two thick, it cools very slowly, and this slow cooling anneals and greatly toughens it, so the difficulty of breaking it up grows very greatly with the size of the body into which it is cast.

When cast in long runners of approximately semicircular shape, a foot across, and six inches thick, it was handled with hooks, one in the hands of each of a pair of men, who broke the runner of cinder up into pieces, three or four feet long, and swung it onto a pile by catching it with a hook near each end. The sections of runner were piled roughly together and allowed to cool still further, after which they were loaded onto

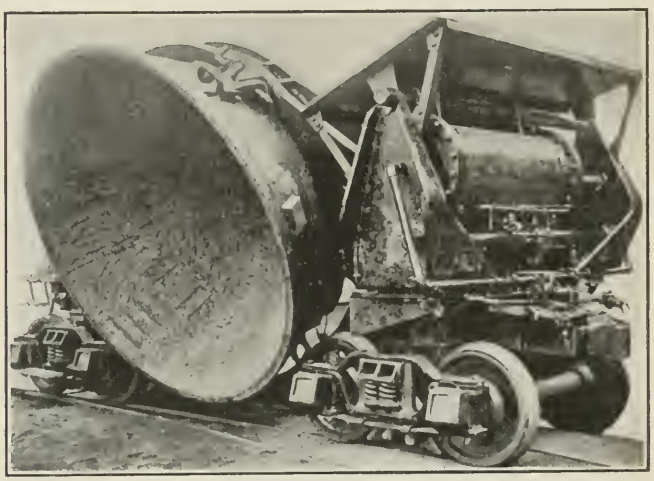


FIG. 16—TREADWELL CINDER LADLE

cars and taken away. This cleared the beds for the next fall of cinder.

In other cases quite large holes, approximately round, were dug into the ground, the cinder allowed to run into these, and a bar or hook of iron stuck into the center while it was still hot. After the cinder had hardened it was picked up by this hook, with the aid of a crane, and loaded for disposal. At the dump the cake was broken up and the hook or bar of iron recovered to be used again.

In other cases the cinder was cast into cakes on cars made entirely of iron, which had a perfectly flat top, so hinged to the body of the car that it could be tipped laterally in either direction. On top of these were set cast iron frames, the section of a truncated pyramid with the sides sloping inward at the top, and without top or bottom. A joint between these and the deck of the car was made with brise or fine cinder, and they were run full of cinder direct from the cinder trough at the furnace. After cooling the iron frames or molds were lifted off with a crane, the train of cars taken to the cinder dump, and the decks tipped, allowing the cakes to slide off over the dump. In this case of

course, as with practically all dumps, the tracks must be moved either laterally or built ahead as the dumping space is used up.

About thirty years ago the practice of handling the slag in the liquid condition began to receive quite general recognition, and has developed continuously and rapidly from that time. The first liquid cinder cars were simply huge rectangular tanks of steel plate, lined with firebrick, mounted on trucks, with a spout closed by a hinged gate at each side. The gate was closed, a little cold cinder thrown against it, and the tank was then filled with liquid cinder and hauled away, At the dump the gate was swung aside and the chilled cinder over the opening broken through, and the contents of the car then ran out. But this method was open to serious objection because even when very quickly handled slag forms quite a heavy skull under such conditions, and this skull fastening itself to the brick-work grows with each successive filling and emptying of the car until the capacity is so diminished that it must be cleaned out by hand, a laborious and time consuming operation. If the car were allowed to stand until the cinder froze on top it made matters still worse as this additional skull also had eventually to be handled by hand.

To eliminate these difficulties cars which dumped their contents by tipping bodily over were developed. These also were at first made of steel plate lined with firebrick, but even when emptied by tipping over they skulled up quite rapidly, and it was finally found that cast iron pots could be successfully used, and that being smooth inside the skull freed itself from them very much more readily than from the brick. These at first were made of the same shape as the steel plate ones had been, with almost straight sides, and flat bottom which gives maximum capacity, but it was found that by increasing the taper of the sides the pots could be made not only to dump cleaner, but to throw out the skull in the dumping position without barring or hand cleaning. Consequently such pots are now universally made with so heavy a taper that they are almost true cones, having only a small spherical bottom.

The design of the William B. Pollock Company is shown by Fig. 15 and that of the Treadwell Engineering Company by Fig. 16. Much ingenuity has been expended in devising the best mechanism for controlling the movement of these pots and dumping them with the least labor. After they had been in use for some years with the dumping gears driven entirely by hand, Mr. Samuel Stewart, then master mechanic of the Woodward Iron Company at Birmingham, Ala., patented a successful design in which a steam cylinder mounted on the car and connected to the locomotive, supplied the power for dumping and restoring the pots to their normal position without any labor and in much less time than was required for the hand-operated pots. This idea has now been applied universally to these pots, but with the very general equipment of locomotives with compressed air for brakes air is used to operate the cylinders instead of steam. With this device a whole train of these cars can be tipped, emptied, the skulls thrown out, and the cars restored to normal position, in a period measured only by seconds.

By the use of these side dump pots the dump may be built up approximately to track level on the dumping side so that the tracks can be moved over with but little labor, when the drop from the cars is no longer sufficient to free them properly, but cars of this type do not permit dumps to be carried ahead except by the laborious method of building up the dump at the end of the track by hand filling.

In order to make room as fast as it is used up, it is generally very desirable to build a track ahead, and for this purpose other types of cars have been devised. The earliest of these was the design of the late John M. Hartman. It consists of a half cylinder of steel plate lined with firebrick, with an extension around the top of cast iron plates, one side of the cylinder being flared out to make a pouring lip and the other side built up vertical. This half cylinder rests on a four-wheeled truck, to which it is fastened by two pairs of chains, one with the front end fastened to the cylinder and the back end to the truck, the other with the back end fastened to the cylinder and the front end to the truck, one pair of these being on each side. These act practically like a rack and pinion and leave the cylinder free to roll on the truck without the possibility of being displaced endwise by sliding; it is guided laterally by angle iron half rings riveted to the cylindrical surface, which work between guides on the truck.

These cars are not coupled directly to the locomotive but by means of a push pole sixteen to twenty feet long. After filling at the furnace these cars are taken to the end of the dump, the truck locked fast on the track with a powerful brake or "scotched," the locking mechanism of the body released and the half cylinder pushed over by the locomotive operating through the push pole which is fastened to the car with a swivel coupling.

The disadvantage of end-dump cars is of course that only one can be dumped at a trip, and if several have to be handled as many tracks must be provided as there are cars, or nearly so, because the heat at the end of the dump is too great to permit dumping one car

FIG. 17—BROWN HOIST CRANE LOADING CINDERS FROM PIT ONTO RAILROAD CARS

immediately after another, and of course a separate switching operation is required for each car dumped, in fact two of them when more than one ladle car is used, one switch to dump the car and set it out, another to pick it up and take it back.

It is a curious fact that these cars build a dump which is almost precipitous in its slope, both on its sides and on the front. A "fill" can be constructed from them with great economy of material because its sides are almost vertical.

On the other hand, the side dumped cars produced very flat slopes. As little as ten or fifteen degrees suffices to carry the slag away from the track with this type of car.

Another type of end dump car with a round "thimble" like that of the side dump car is made by the Treadwell Engineering Company and works with a similar mechanism, but fore and aft instead of laterally. It is of course a more difficult design because the truck is in the way

of a free end-dump, but this difficulty has been successfully overcome.

How a slag dump is to be handled is very largely a matter of local conditions, but I have always felt that the benefits of the end dumped car for building ahead

FIG. 18—BROWN HOIST TRAVELING CRANE AND GRAB BUCKET FOR HANDLING CINDERS

were not properly appreciated, and that the ideal combination would be two or three, or even four or five side dump pots with an end dump pot on the front. With this arrangement all could be dumped simultaneously without switching, and the end-dump pot would build ahead about as fast as the side-dump pots used up the track room it provided.

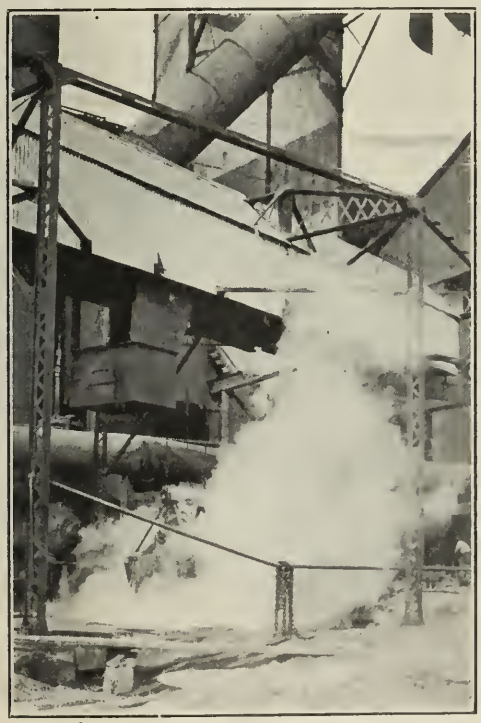


FIG. 19—BROWNING GRAB BUCKET RISING OUT OF PIT WATER DRAINING OFF

The "hot pot" method of handling slag is economical for a large plant of furnaces, and where dumping room is available within a reasonable distance; but in congested districts where the only available land between high bluffs and a river is a narrow strip of bottom, every inch of which is necessary for plant and railroad tracks, it is not always easy to find a place in which to dispose of the slag without a long chance that one will be exceedingly sorry for having put it there later on. Of course if a river or harbor can be filled to the harbor line this makes an ideal condition, but one which will not last indefinitely. Moreover, this method of handling slag requires a locomotive and crew in absolutely constant attendance day and night, Sundays and holidays. If the cinder cars get off the track, which not infrequently happens on the rough tracks on the dump, and the cinder train is blocked, the furnace may be put to desperate straits before the situation is relieved by the return of the cinder cars. The expense of the locomotive and crew is just as great for a single furnace as it is for three or four, and the cost of slag disposal per ton of iron produced is therefore very much heavier by this method in small plants than in large ones.

Granulation

These difficulties have prevented the universal adoption of this means of slag disposal, and have caused the development of others, of which by far the most important is "granulation." This was first practiced in this country, so far as known to me, by Captain T. C. Jones, I think, at a small blast furnace near Lynchburg, Va., and was subsequently applied by him, and still continues in use, at a furnace at Iron Gate, Va., where the slag is flushed directly into the James River and carried away by the current of that stream. The method consists in running the cinder out through a trough with a projecting end, just beneath which is placed a flat jet or nozzle about the same width as the trough. When the cinder starts to run a powerful current of water is turned into this nozzle, and the cinder running from the end of the trough falls onto this jet whose velocity is sufficient to tear the cinder into small shot as it runs, and these, of course, are prevented from recementing by the chilling action of the water.

FIG. 20—BROWNING GRAB BUCKET OPEN OVER PIT

Most plants which use this method of slag disposal are not so located that they can flush the cinder directly into a river, and these have installed a huge concrete lined pit or tank sunk in the ground, into which the cinder and water from the jet fall together, and from which the cinder is recovered, generally by means of a clam shell bucket, and loaded onto cars. It is by that time cold so that there is no danger of fire; the cinder

is between course sand and fine gravel in size, generally rounded, and a very easy material to handle. It of course may be carried any distance desired to make fills on railroads, or the like, since the time element does not enter into its disposal as it does when handled liquid, and it can be handled virtually without expense in outward bound empty cars, and has in the past been very generally handled in this way by the railroads, without charge on account of its value to them as a filling material.

The clam shell bucket for recovering the cinder from the pit is operated in various ways, either by an overhead crane, a crane trolley without lateral movement, or by a locomotive crane running on a standard or broad-gage track. An arrangement of the latter kind may be seen in Fig. 17, which shows a Brown Hoisting Machinery Company crane engaged in this service. The pit cannot be seen, but its position can be judged from the ropes running from the end of the boom down to the clam shell which is out of sight in the pit, also

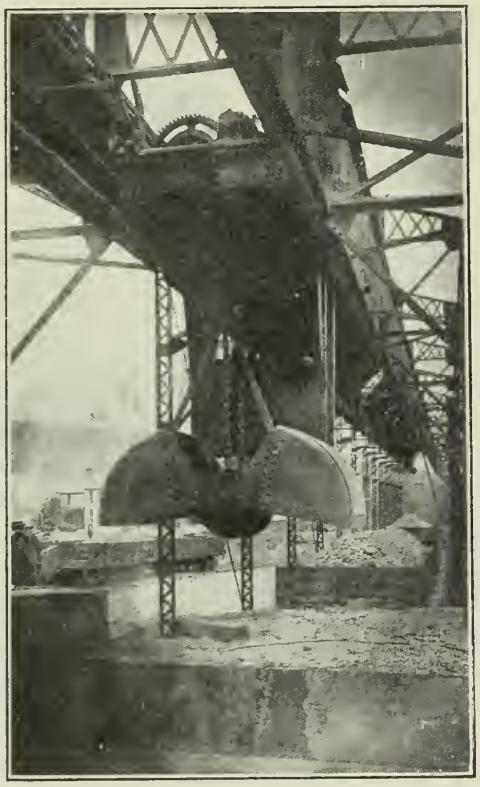


FIG. 21—BROWNING GRAB BUCKET OPEN OVER PIT

by the steam rising from it. The granulated cinder is raised out of this pit and swung over into the hopper cars from which steam is seen rising on the right hand side of the picture.

Fig. 18 is a view of the same plant and crane from a different position. The pit may be distinguished by the steam rising from it at the extreme left of the picture, while the white granulated slag in the car showing just under the crane boom is plainly visible.

Fig. 19 shows a clam shell operated from a trolley on an overhead runway, installed by Victor R. Browning & Company of Cleveland. The clam shell just at the top of the pit may be clearly seen with the water contained in the slag running from it. The clam shell open, dropping into the pit, is more plainly shown by Fig. 20. In this the perforations in the bucket for allowing the water to run off are plainly visible. The clam shell in its open position with the cars of loaded slag under the runway, are clearly shown by Fig. 21.

A different design by the same company of the same general arrangement is shown by Fig. 22

The trolley for handling the bucket with its mechanism and the operator's cage are shown by Fig. 23.

This method of handling slag has the great advantage that it gives several hours leeway, since slag can be stored in the pit without requiring to be removed for a

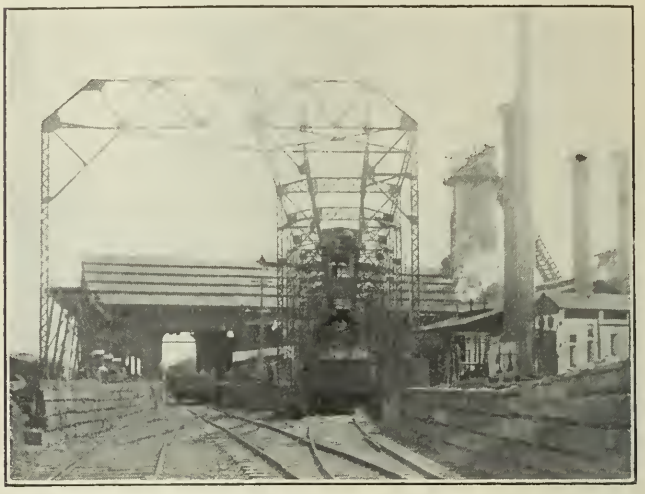


FIG. 22—BROWNING CRANEWAY WITH TROLLEY AND GRAB BUCKET

considerable period, so that breakdowns of the slag handling apparatus may occur without necessitating the shutting down of the furnace.

By providing a pit a little larger than common it would be very easy to store the slag for twelve hours or more, and so eliminate the operation of the slag trolley on one shift. Where the railroads take the slag, and the shifting engine is available for handling empty and loaded cars, this method is more economical for a single or even for a two-furnace plant than the liquid cinder method because it can be run by a single oper-

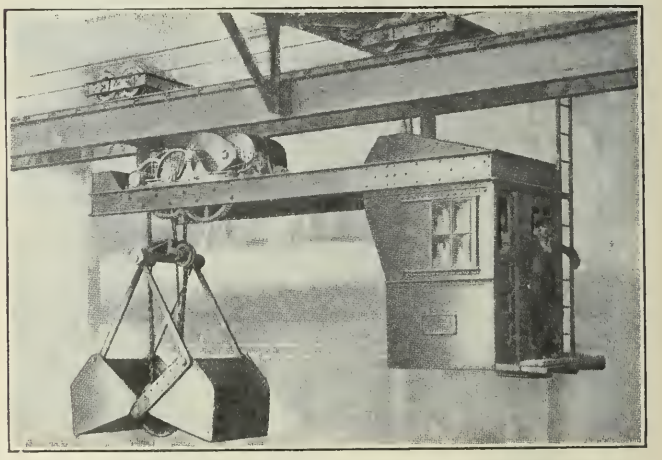


FIG. 23—BROWNING MAN-TROLLEY AND GRAB BUCKET

ator, whereas the other requires a locomotive and crew of two shifts as before stated.

Casting the Cinder and Handling It Cold

In recent years, since the very general introduction of concrete, it has been realized that slag allowed to cool slowly made one of the best aggregates that could be found, much better than limestone, because being of igneous origin it does not break up under the action of heat, as limestone has been known to do in case of fire.

Cinder is exceedingly rough and therefore furnishes an excellent bond for the cement, and in general cinder concrete is very highly esteemed by those who have used it.

Cinder is often recovered for concreting and road filling purposes by blasting the dumps made by ladle cars and loading them up with a steam shovel, but the cinder has generally run out in thin sheets which do not weld together, so that the mass breaks up into quite small pieces when it is reloaded. Moreover, this process requires the double operation of removing the cinder in pots and then picking it up with the steam shovel.

Mr. D. T. Croxton, of the Cleveland Furnace Company, some years ago, initiated the plan of casting the cinder directly from furnace in the old-fashioned way, but handling it by mechanical means after it was cold, crushing, screening and selling it for concrete material.

After a course of development for several years in which he installed a considerable quantity of special machinery, he finally came down to the simple practice of bedding heavy chains into the cinder bed before casting the cinder into it, these chains being covered up so as to prevent the slag from burning them. The slag bed is served by an overhead crane which takes hold of the ends of the chains at the sides of the bed and pulls them up through it. These chains are spaced a few feet apart and this breaks the slag bed into a material which can readily be picked up by a modern clam-shell bucket and loaded into cars for delivery to the crushing and screening plant.

This system without the mechanical equipment for handling the slag has been in use at other places where the slag has a commercial value as filling or building material.

One considerable advantage of handling the slag in this way is that a magnetic separator can be introduced into the path of the crushed slag and used to recover from it a considerable quantity of iron in pieces from the size of a pin head up to several pounds weight. This is true even with good furnace practice and where no important quantity of iron is visible to the eye, since the iron is so much heavier than the cinder that it goes to the bottom and is covered over by the latter.

It has been the experience of almost everyone who made any attempt to recover iron from the slag to find more than was expected when the attempt was begun. I myself had once the pleasant experience of putting in a magnetic separator in the hope of recovering four or five tons a month from a charcoal furnace, and actually recovered fifteen to twenty-five.

Many other methods of handling cinder have doubtless been used and perhaps a considerable number of these are still in operation, but the ones here described cover all the important methods in use on a large industrial scale.

The sampling and analysis of coal is treated at some length in *Technical Paper* 76 of the U. S. Bureau of Mines. Methods of sampling and analysis and interpretation of results are given in detail.

The Electric Furnace in Metallurgical Work is the title of *Bulletin* 77 of the U. S. Bureau of Mines. It is a compilation of data and useful information for the use of persons interested in the subject. Part I, by D. A. Lyon and J. F. Cullen, is devoted to the design, construction and operation of electric furnaces; part II to the smelting of metals in the electric furnace, by D. A. Lyon and R. M. Keeney; and part III to the manufacture of ferro-alloys in the electric furnace by R. M. Keeney.

The Arizona Copper Co. produced 1201 tons of copper during December, 1914.

Tube-Milling for the Flotation or Oil-Concentration Process

BY W. B. EASTON

In the December number of *Metallurgical & Chemical Engineering* there is an interesting article by Mr. W. J. Pentland, entitled "Notes on Tube-Milling in All-Slime Cyanide Practice." Under heading, "Duty of Tube Mill," Mr. Pentland questions the use of the tube-mill in closed circuit as being the most efficient method of using that machine. In regard to this phase of tube-mill practice, one hears the statement so frequently nowadays by engineers and millmen generally, that *"the most efficient machine is the one which keeps the greatest quantity of pulp in closed circuit,"* that I had nearly ceased to consider it as a debatable question. However, this statement may be no more axiomatic than the one that "the proper percentage of moisture for tube-mill feed is 38 per cent."

During the summer and early fall of 1914, I spent three months daily watching the operation of a 72″ x 20′ tube-mill. This tube-mill was fitted with the Chalmers & Williams patented adjustable quick discharge, and was running on split feed with conical tube-mills crushing copper ores for the flotation or oil-concentration process.

It is not the purpose of this article to make comparisons of the work of the two types of machines, but to use the results of some of the observations made during this time to throw some light on the question of the desirability of operating a tube-mill in closed circuit with a classifier, in order to obtain the highest efficiency from the tube-mill; and, incidentally, to show that with this type of tube-mill at least, there is no law which makes it necessary for the tube-mill feed to contain 38 per cent of moisture, for the percentage of moisture in the feed varied from so dilute a pulp as two parts of water to one part of ore, to only 29 or 30 per cent moisture.

The tube-mill under observation was used to prepare ore for treatment by the oil-flotation process for recovering the mineral; but the same conditions which would make the mill most efficient for this work would also make it most efficient for preparing ore for treatment by cyanide or, in fact, any subsequent process. It was decided, in order to get the best results from the oil-flotation process, to have the pulp as it left the classifier contain about 2½ parts of water to one part of ore, as it was desired to send the pulp directly to the oil-flotation machines without the intermediate operation of dewatering it. Naturally the work of the classifier was very materially affected by this thick pulp, but in reducing the capacity of the classifier to separate the finished product from the oversize, it brought out very clearly the effect of the classifier on tube-mill efficiency; for, if the classifier had been of ample capacity to do efficient work, the results observed on account of its lack of capacity would not have been noticed.

Effect of Classifier on Capacity

It was observed that when feeding the tube-mill with material 6-mesh and finer, at the rate of 144 tons dry ore per 24 hours, about 8 per cent of the product remained on 100-mesh screen, with about 70 per cent of minus-200. Practically no material was returned from the classifier, so that in effect the tube-mill was producing a finished product as above. In order to maintain the desired density of the pulp flowing from the classifier, it was not practical to send the feed to the classifier, but directly to the tube-mill, using the classifier only to separate and return to the tube-mill the oversize from its product. When the feed was in-

creased substantially to more than 144 tons, oversize began to be returned by the classifier. About 210 tons per 24 hours was the limit of capacity of the classifier, when making a clean separation.

When the tube-mill was fed at the rate of 240 tons per 24 hours, a screen analysis of the classifier overflow showed 15 per cent remaining on 100-mesh screen, with about 56 per cent minus-200; and in the return to the tube-mill from the classifier there was 22 per cent plus-100 and 16 per cent minus-200. This showed that if the classifier had had capacity to separate the oversize from finished product, the 16 per cent of minus-200 which was returned with the oversize to the tube-mill would have passed out with the discharge from the classifier, making a total of 72 per cent minus-200; and if in making this separation 7 per cent of the material under 60-mesh and on 100-mesh had passed out from the classifier with the oversize where it belonged, there would have been left the 8 per cent on 100-mesh in the overflow as in the first case.

Under the first condition, with the classifier practically inoperative and returning no oversize, the tube-mill was making 92 per cent of 144 tons, or 132.48 tons, of minus 100-mesh. In the latter case the tube-mill in connection with the classifier returning oversize, was grinding 92 per cent of 240 tons, or 220.8 tons, of minus 100-mesh product; but the classifier did not do its work properly, as 30 per cent of the material returned to the tube-mill was minus 100-mesh and considerable oversize went off in the overflow from the classifier. Later when the classifier was changed it was found that there was no more plus 100-mesh product made when the tube-mill was grinding at the rate of 240 tons per 24 hours, with a classifier returning the oversize, than there was when it was grinding at the rate of 144 tons per 24 hours with no oversize returned from the classifier. These results would indicate that the efficiency of the tube-mill was decidedly greater when worked in closed circuit, than when it was attempted to deliver a finished product direct from the tube-mill in open circuit.

Results at a later period, when a still larger classifier had been installed, showed that the tube-mill worked even more efficiently when fed at the rate of 288 tons per 24 hours. In fact, every time during this period of three months when we thought we were beginning to reach the capacity of the tube-mill on a certain feed and to produce a certain mesh product, we would find that what we had really determined was the capacity of the classifier used in connection with the tube-mill and not the capacity of the tube-mill itself or of an efficient combination of tube-mill and classifier.

Effect of the Pulp-Load on Efficiency

A recording watt-meter was used in connection with the motor driving the tube-mill, and the observations taken from this record showed that the load of pulp which the tube-mill was carrying had a most decided effect upon the ultimate duty or efficiency of the tube-mill by its effect upon the power necessary to drive it. With a feed at the rate of 144 tons per day containing about 40 per cent moisture, the motor took 75 kilowatts. With a feed at the rate of 240 tons per day containing about 38 per cent moisture, the motor took 62 kilowatts. At another time with a feed of 180 tons per day with 38 per cent moisture, the motor took 70 kilowatts. By reducing the moisture in the tube-mill discharge to 30 per cent, by increasing the amount of material returned from the classifier, thus making a heavier floating load in the tube-mill, the power was reduced to 65 kilowatts. When the tube-mill was fed at the rate of 350 tons per 24 hours, feed containing about 40 per cent moisture, only 55 kilowatts was required to drive it. It would seem clear, therefore, that in making a comparison of the first two conditions, namely, (1) grinding 144 tons of dry ore all from 6-mesh feed to minus 100-mesh product, without any classifying; and (2) grinding 240 tons of dry ore all from 6-mesh feed to minus 100-mesh product with a classifier returning the oversize; it is evident that, not only was the capacity increased by using the classifier in closed circuit with the tube-mill, but the efficiency of the tube-mill was also increased by having a greater floating load, due not only to its ability to handle a larger amount of floating load, but also to a greater floating load from the amount of oversize in the closed circuit. The reduction in power necessary to drive it was from 75 kilowatts to 62 kilowatts.

To emphasize this point: If we assume that power costs 1 cent per kilowatt hour, then the cost for power per ton of ore ground in the first case would be twenty-four hours times 75 cents, amounting to $18.00 for 144 tons of ore, or 12½ cents per ton. In the second case, the cost for power per ton of ore ground would be 24 hours times 62 cents, amounting to $14.88 for 240 tons

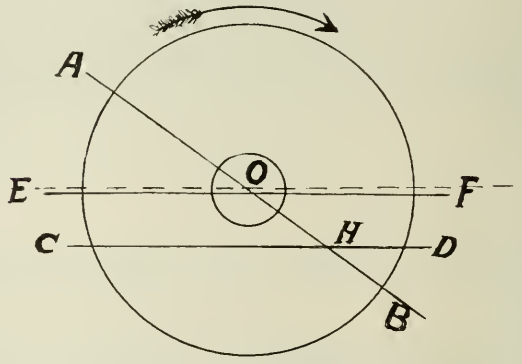


FIG. 1—CROSS-SECTION THROUGH TUBE-MILL

of ore, or 6 2/10 cents per ton. This certainly is one answer to the question as to whether the tube-mill is more efficient when operated with or without a classifier in closed circuit.

The results of my observations over this period of three months on this particular tube-mill, showed plainly that, with a given load, the power decreased very rapidly as the density of the pulp was increased, starting with a density of two parts of water to one part of ore and reducing the amount of water to 30 per cent. This was the greatest density obtained at any time, but there was no indication of congestion or clogging; and with a load at the rate of 240 tons per day, I would have liked to reduce the moisture still further if it had been practical. Of course the adjustable quick discharge attachment had the effect of lowering the discharge opening below the feed opening and increasing the flow of pulp through the tube-mill.

The pebble load is an unbalanced load. The pulp, or the floating load, is a balanced load. Any increase in the weight of the latter, due either to increasing its density or increasing the amount by carrying a greater quantity of material in the circuit, is bound to decrease the power necessary to drive the tube-mill. Referring to Fig. 1, let AB represent approximately the pebble load in action; let CD represent a certain pulp-load level; let EF represent another pulp-load level; let O represent the center of discharge opening. Then the more closely the triangle BHD approaches the triangle BOF in quantity or the triangle AOE in weight, or both, due to increased density, the less will be the power required to drive the mill. The instantaneous effect of changing this factor in the operation of the tube-mill, as shown by the recording watt-meter, was most interesting, and both the mill crew and visitors were much surprised at the results shown.

Chicago Heights, Ill.

The Use of Hydrometallurgical Apparatus in Chemical Engineering

BY JOHN V. N. DORR

(*Concluded from page 59 of the January issue*)

The Dorr Thickener

The Dorr thickener was developed by me in 1906, when, in remodeling a mill in the Black Hills, I desired to thicken the slime pulp from classification continuously in large units and avoid the use of the large cones which accumulated solid slime on the sides and gave much trouble.

The trial machine was operated in a tank 35 ft. in diameter by 12 ft. deep at a speed of 1/20 r.p.m. and gave excellent results, continuing in operation until the mill burned five years later.

DESCRIPTION

The Dorr continuous thickener consists of a slow-moving mechanism placed in a suitable tank, by means of which the operation of settling may be made continuous through the removal of the settled material to a point of discharge and the prevention of its accumulation as a solid in the tank.

As usually furnished, it consists of a central vertical shaft with radial arms equipped to bring the thickened material to a discharge opening at the center by the slow rotation of the mechanism. The thick material may be discharged by gravity at this point into a launder, or piped to the side of the tank and raised by air lift or pump to the level of the overflow or higher.

The machine is arranged for raising the shaft so that the arms will not be imbedded in the thick material if the power should be shut off for any length of time. The shaft can be lowered again gradually while running. Shaft and gear bracket are supported by a bridge over the tank or suspended from the roof trusses (Fig. 5).

In one case, at the Liberty Bell mill, thickeners have been installed driven from below the tank through a mercury bearing, and proved efficient, although they cannot be raised.

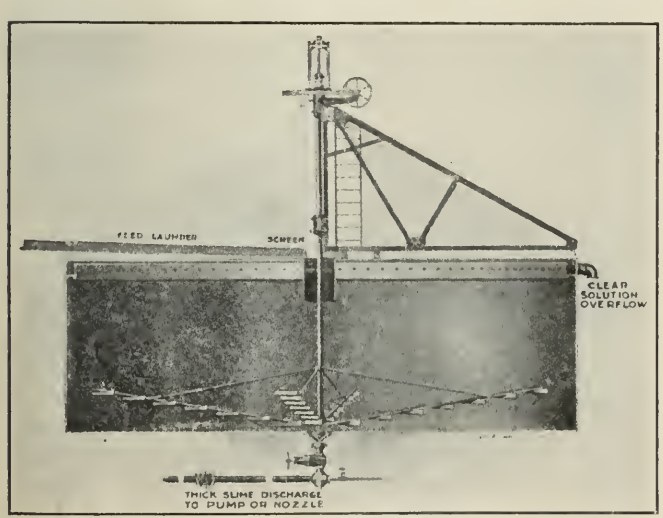


FIG. 5—DORR CONTINUOUS THICKENER

The thin pulp is delivered near the center of the tank in a suitable well with a float to cause minimum disturbance, and the overflow is taken off by a peripheral launder.

The thickened pulp can be accumulated and withdrawn at intervals, or a continuous discharge maintained, as desired. Nozzle discharge is in use in some concentrating mills where a comparatively thin pulp is desired, and also in one case where a product of only 30 per cent moisture is being obtained. Many are using diaphragm pumps for this purpose. They have the advantage of ready regulation and require little attention. Having a positive displacement, they tend to regulate automatically the amount of solids withdrawn, for, when the pulp becomes thicker, more solids are pumped with each stroke. A pet cock to admit air into the suction has proved most satisfactory as a means of regulation.

SPEED

The thickener has been operated at speeds ranging from 1 revolution in 2 minutes to 1 in 40 minutes. A quick-settling sandy material will offer great resistance unless a comparatively high speed is maintained, while colloidal slime will give a slightly thicker underflow, at a very slow speed. It will be found when handling sandy material that if the sand accumulates so that it is being moved around the tank by the channel arms as well as being advanced toward the center by the plows the resistance increases rapidly and the speed should be increased.

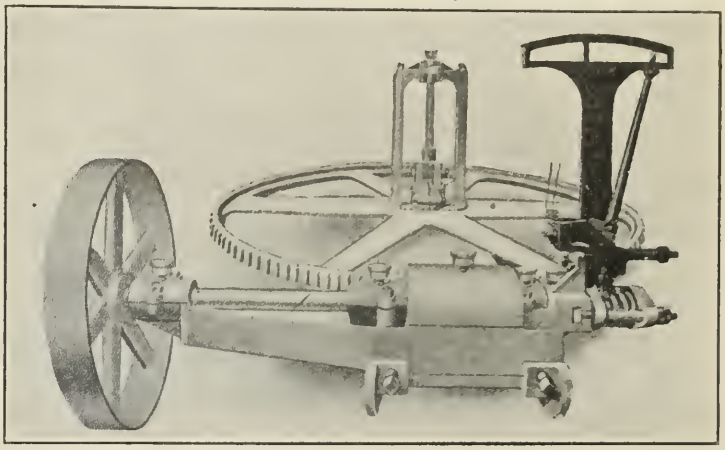


FIG. 6—OVERLOAD ALARM AND RESISTANCE INDICATOR ON DORR THICKENER, WITH ARRANGEMENT FOR RAISING SHAFT WHILE OPERATING

POWER

This varies with the size of the tank and the nature of the feed. Of course, the motor input is much larger than the actual power consumed, owing to the low load factor commonly used, as it is essential to have power enough to meet an unusual strain. Spring measurements have shown approximately 1/20th hp. being transmitted to the worm shaft of a 44-ft. thickener handling a classified slime. It would not be advisable, however, to install less than a 1-hp. motor on a single machine, but ½ hp. each can be allowed when several are driven from one lineshaft.

REPAIRS

Normal operation of the thickener causes no wear except on the worm, and many machines are running to-day that have not cost a cent for several years. On the other hand, if started after a shutdown without raising, a strain of any amount may be given so that the "weakest point" would have to yield.

The overload alarm, Fig. 6, is arranged to indicate the resistance offered by the mechanism as shown by the thrust on the worm shaft and to ring an alarm when the load becomes excessive. A solenoid or other means can be used to correct automatically the condition causing the excessive load, by reducing the feed or

increasing the underflow. The alarm has proved very valuable, especially on quick-settling pulp, when it is desired to obtain the thickest discharge.

LABOR

The attendance required varies with the regularity of conditions maintained and is usually confined to lubrication once a shift, so that the care of the thickeners is included in the duties of some man employed principally on other work.

CAPACITY

The capacity of Dorr thickeners on any pulp has been found to be primarily a function of area, although the depth of the tank has an influence depending on the dilution of the feed and the dilution of the underflow desired. With a given area and depth and a very dilute feed and underflow the capacity depends on the amount of liquid that can be clarified; i.e., additional solids, but no additional liquid, can be added to a tank already fed to capacity without overflowing slime. On the other hand, with a feed perhaps 8 of liquid to 1 of solids and a thick discharge of 2 to 1 or less, it will be found usually that additional liquid can be added to a thickener operating at capacity without overloading it, but any addition of solids will cause slime to overflow.

If a plant requires more settling capacity, raising the temperature of the solutions may prove an economical way to add 10 to 20 per cent. The capacity of any filter can also be increased by this means.

Table II represents data given me from time to time. It shows the settling area in use per ton in different mills which in many cases were not feeding their thickeners at capacity.

DENSITY OF UNDERFLOW

This depends on the nature of the pulp to be settled and the size of the particles. An argillaceous pulp, such as that at the Liberty Bell in Colorado, although containing a large percentage of reground siliceous material, will not settle thicker than 60 per cent moisture, while a finely ground quartz will give as low as 27 per cent moisture. At the Porcupine-Crown plant, handling a quartz product of 75 per cent minus 200 mesh, the average final pulp discharged contains 30 per cent moisture with the feed at the rate of 1 ton of solids per day for each 4.7 sq. ft. of tank area.

We have no reason to think that the use of the Dorr thickener will increase the amount of water that can be clarified in a given settling area at the beginning of the flow into the tank, but the removal of the pulp as rapidly as it settles certainly avoids the decrease in the settling rate which would follow when a tank is filling up in intermittent settling.

At one plant where reground ore pulp was thickened from 10 to 1 to approximately 2 to 1, actual experience indicated that the change from intermittent to continuous settling enabled three tanks equipped with Dorr thickeners to do the work of five used intermittently.

THE DORR TRAY THICKENER

The original thickener was installed in a tank 12 ft. deep and we adhered to approximately that depth, varying from 6 to 16 or 20 ft., for a number of years. One reason for this was that it early showed itself to be an advantage to have ample storage capacity for thickened slime at the bottom of the tank. It not infrequently happens that the flow of slime to the settling tank will vary during the day and the settling qualities of the slime may vary as well so that if the feed is light a large quantity of clear liquid accumulates on the top of the thickener, which when more slime comes, flows away, together with the freshly clarified water and partly thickened slime takes its place, thus giving a great reserve capacity.

Table II—Operating Data on Dorr Thickeners

Mill	Sq. Ft. Settling Area per Ton of Solids Thickened per 24 Hr.	Sq. Ft. Settling Area per Gallon Overflowed per Minute	Remarks
San Rafael, Mexico	4.5	.	Tube-mill product, 75 per cent. −200 mesh, discharge 45.5 per cent. solids.
Liberty Bell, Colorado.	15.0	12.6	Tube-mill product, much light argillaceous slime. Discharge 33 per cent. solids: + 100, 17 per cent.; + 200, 13 per cent.; − 200, 70 per cent. Feed 9:1. Solution fed at capacity; solids not. Large area per gallon overflowed per minute due to density of underflow and nature of the slime.
Mogul, South Dakota.	3.92	. . .	Tube-mill product; ore siliceous: + 60, 0.6 per cent.; + 100, 7.8 per cent.; + 200, 26 per cent.; − 200, 65.6 per cent. Discharge 56 to 59 per cent. solids. Continuous decantation.
Batopilas, Mexico	0.6 to 0.9	.....	40-mesh product; 90 per cent. passing 100 mesh.
Zambona, Mexico	3.1	.....	Tube-mill product. Discharge 40 per cent. solids.
Dominion, Ontario	5.4	.....	Tube-mill product, 88 per cent. − 200 mesh, ore diabase. Discharge 40 per cent. solids. Feed 6:1.
Porcupine-Crown, Ontario.	4.25	.....	Tube-mill product, 75 per cent. − 200 mesh. Discharge 65 per cent. solids. Quartz ore. Continuous decantation. With 5.1 sq. ft. settling area per ton settles to 71 to 73 per cent. solids.
El Palmarito, Mexico.	4.5	.....	Tube-mill product: pure quartzite, 97 per cent. − 200 mesh. Feed 7:1. Discharge 65 to 70 per cent. solids. Continuous decantation.
Amparo, Jalisco, Mex.	4.9	1.4	Tube-mill product, siliceous: 93.5 per cent. − 200 mesh. Feed 24.5:1. Discharge 23.5 per cent. solids: used to feed vanners.
Veta Colorado, Parral, Mex.	5.0	3⅓a	Tube-mill product, rather argillaceous: 71 per cent. − 200 mesh. Feed 11:1. Discharge 33 per cent. solids for agitator Have settled to 65 per cent. solids.
Smuggler-Union, Telluride, Colo.	.....	.....	Very clayey slime with classified sand. Screen test: + 40, 1.48 per cent.; + 60, 7.27 per cent.; + 100, 14.81 per cent.; + 200, 11.63 per cent.; − 200, 65.81 per cent.
	30.0	26.0	Settling from cold water, slightly alkaline. Feed 8:1. Discharge 50 per cent. solids, 1.429 sp. gr.
	10.0	.....	Settling from cyanide solution. Feed, 2.5:1. Discharge 40 per cent. solids, 1.316 sp. gr.
A large copper company, Arizona.	11.6	8.11	Considerable argillaceous slime. Feed 10.4 per cent. solids. Discharge 25.3 per cent. solids.
Pennsylvania Steel, Lebanon, Pa.	14.2	2.48	Thickening ahead of vanner concentration. Feed 2.8 per cent. solids. Discharge 10.6 per cent. solids. Overflow 0.4 per cent. solids, extremely fine, which does not interfere with using water again.
Nevada Consolidated, Ely, Nev.	... ..	1.25	"Each 17-ft. thickener supplies wash water for 20 Wilfley tables and occasionally for wash on vanners. One thickener has a greater capacity than twelve 8-ft. cones." Area of 17-ft. tank is 226 sq. ft.; of the twelve 8-ft. cones, 525 sq. ft.
Broken Hill, Proprietory, Australia.	.....	1.80	Dewatering slime from lead-zinc concentration mill. Feed 100:1. Dischrage 55 per cent. solids.
Anaconda Copper, Mont.	.....	5.95	Dewatering slime from concentrator. Forty 4-deck thickeners, each 28 ft. in diameter by 3 ft. 3 in. deep, handle about 26,000,000 gal. of pulp per day which contains approximately 2 per cent. solids. A clear overflow obtained, the underflow containing about 15 per cent. solids, which is fed to buddles.

The data given here show that when pulp is carried in cyanide solution a provision of 5 to 6 sq. ft. per ton for a siliceous tube mill product is ample and from 7 to 15 sq. ft. for a clayey material or classified slime product. When very dilute products are handled the area required is determined usually by the gallons per minute to be overflowed.
*Not up to capacity of overflow.

In 1913, however, I had occasion to go into the question of securing large settling capacity with small floor space and developed what I have called a tray thickener. There are two types of this. The first, which would seem to be the simplest, has been installed by the Anaconda Copper Company and in the Coeur d'Alenes. It consists of two or more shallow tanks, each carrying thickening apparatus attached to a common shaft and acting as independent units with its own feed, clear water overflow and thick slime discharge. Tests made by the Anaconda Copper Company indicated that with their material tanks 28 ft. x 3 ft. would handle approximately 90 per cent of the material, that tanks 28 ft. x 9 ft. would handle so that this gives them a great economy in plant construction.

Fig. 7 shows this type and represents one of forty

tray thickeners installed in their settling plant, which is handling 26,000,000 gal. of water a day and separating therefrom 2500 tons of extremely colloidal slimes. Each tray is a separate unit, with its own feed, thickened discharge and clear outflow.

The second type of tray thickener, which I have called the submerged type (Fig. 8) was tested first at the Homestake Mill at Lead, South Dakota, and consisted as tried there essentially of a shallow thickener and tank entirely submerged in a cone-bottom settling tank. The space below the small thickener had its own feed and discharge and the clear water overflowing from it joined the overflow of the shallow thickener tank. The latter has its own feed and discharge as well.

Fig. 9 gives the result of tests made there to show comparative capacities of tanks with and without the tray. Applying the idea to thickeners already installed, Fig. 9 shows the installation of a tray in a standard deep thickener. It gives in effect two tanks, each with its own feed and discharge, and a combined overflow, and in practice has resulted in enabling us to add 70 to 100 per cent to the capacity of plants already in opera-

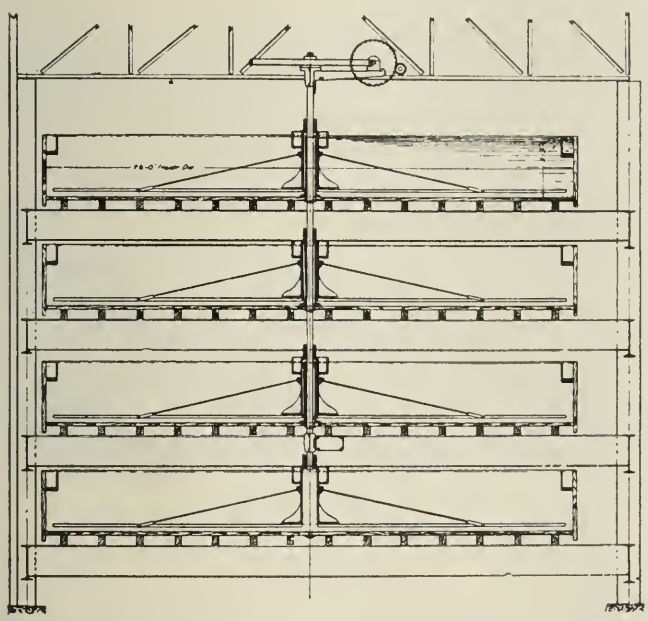


FIG. 7—THE DORR TRAY THICKENER, SUPERPOSED TYPE

tion. It has been found unnecessary to make this tray strong enough to support these tanks filled with liquid if the space below it is empty, as by means of an automatic float we have arranged to make connections between the upper tank and the lower in case the level of the liquid drops in either. It will be evident, I think, that these trays will afford means of obtaining a large amount of settling capacity with comparatively small floor space, and we are working now on their further development.

LARGE THICKENERS

For a long time the largest thickeners in use were in tanks 50 ft. in diameter by 20 ft. deep, at the Nevada Consolidated Company. Within the last year, however, the Arizona Copper Company has installed a Dorr thickener in a tank 130 ft. in diameter. Fig. 10 shows the machine in operation. It has proven entirely successful and indicates the possibility of furnishing very large unts which will cost less per square foot of settling area than the smaller ones. The tank in this case is merely a ring of concrete erected on a slag dump, the settled slime forming its own bottom. It is probably as large as any we would care to build, but we anticipate building up to 100 ft., using the bridge and central shaft, which we now use on our standard machine.

This large thickener has handled over 1200 tons of solids and Mr. David Cole, the company's engineer who designed and installed it, estimates that it would

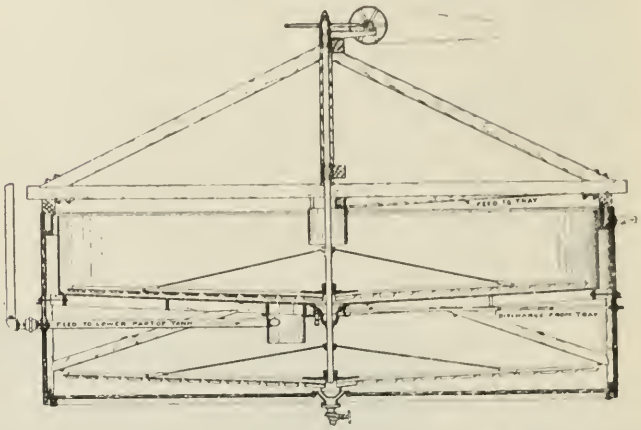


FIG. 8—THE DORR TRAY THICKENER, SUBMERGED TYPE

take care of 2000 tons of material 40 mesh and finer. Its overflow has been over 3,000,000 gal. per day, and its limit of capacity has not yet been reached. The net saving in water by the use of this machine with the mill at capacity is $120 per day.

It has proved feasible under some conditions to install a Dorr thickener in a rectangular settling tank and get good results.

USES

The thickener was originally introduced in cyaniding for thickening slime or reground pulp previous to agitation and filtration, and came into general use for that purpose. Within the last few years it has proved a

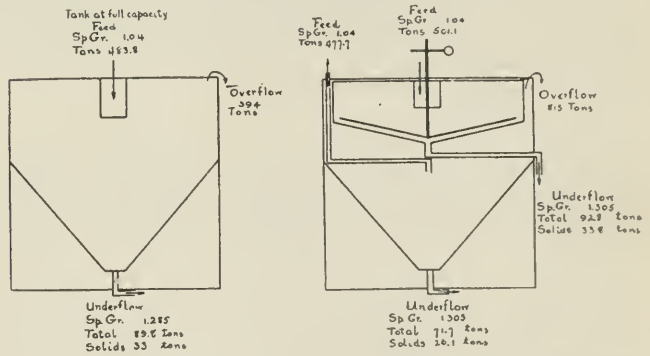


FIG. 9—TEST OF DORR TRAY THICKENER AT HOMESTAKE MILL, LEAD, S. D.

means for recovering the dissolved value as well by continuous counter-current decantation, which will be spoken of later. Its use in thickening ahead of slime concentration has become very general, nearly all the large copper and lead companies having adopted it within the last few years.

The development of flotation concentration has opened a new field for the thickener, the machine being used in most of the plants in this country and in Australia for dewatering both ahead of the flotation boxes and, in some cases, after them as well, also for collecting the concentrates and recovering warm water from the tails for reuse.

INDUSTRIAL USES

The thickener presents great opportunities for the recovery at an extremely small expense of all kinds of

finely divided residues that go to waste or are recovered intermittently from settling ponds. The expense, including interest on equipment, amounts in one case to 1 mill and in another 2 mills per 1000 gal. clarified. In both cases the solids removed were colloidal ore slimes. One plant recovering a finely divided organic material from settling ponds substituted the Dorr thickeners for them and I am advised saved the labor of 12 men per day. Its use for removing heavy silt in water purification seems possible with the large units now feasible.

Sewage treatment and its use for the prevention of stream pollution looks promising. A plant is now planned for the recovery of precipitated ferric-hydrate from mine water.

In all industrial work its use to furnish a much thicker product to a filter press will mean great increase in the capacity of the press with diminished costs.

CONTINUOUS COUNTER-CURRENT DECANTATION

Continuous counter-current decantation consists of the operation of a series of settling vessels in such a way that the solids to be treated continuously pass through them in succession, being diluted after each thickening by solution from the overflows passing in the opposite direction.

The objects to be attained are the dissolution under most favorable conditions of a portion of the solids, the separation of a solution from a finely divided solid with minimum dilution, or both combined.

The last result is that usually obtained in metallurgical work, as the separation of most of the dissolved material from the solids always occurs, and even when apparently adequate means for dissolution are provided ahead of the system the favorable conditions afforded usually give an additional extraction.

HISTORY

I will not take time to go into detail as to the history of continuous counter-current decantation, but simply say that the principles are very old and have been applied in many ways in chemical technology as well as in metallurgy.

The first cyanide plant using this method in the United States was erected by John Randall in the Black Hills in 1902, using large cones for settlers, and was operated for a year. The invention of the Dorr thickener in 1906 gave an opportunity to avoid the troubles inherent in cones, and in 1910 the first modern plant was started. Since that time there have been a large number of plants installed, several of them replacing vacuum filters, so that it may be regarded to-day as one of the well-established methods of cyaniding. Several years ago Dr. R. Gahl successfully operated an experimental plant with cone settlers, leaching copper ore slimes with sulphuric acid, treating seven or eight tons daily, to which he refers in a paper* read before the American Electrochemical Society. A test plant of 75 tons capacity is now starting, using thickeners.

The following description of a typical flow sheet of a continuous counter-current decantation cyanide plant will undoubtedly explain the process further, and also show the method we have used to determine the results that may be expected from any conditions assumed.

The square marked Mill, in Fig. 12, represents the grinding machinery, and we assume the ore is crushed in cyanide solution which brings the fine pulp continuously into thickener V, whence the solids pass through the agitators and thickeners W, X, Y and Z until discharged from Z as tailings.

Transactions American Electrochemical Society, vol. XXV, page 243 (1914).

All the figures on the flow sheet refer to tonnages of liquid per day.

The following conditions are assumed:

1st. The thick pulp underflows are thoroughly mixed with the clear overflows before entering the next tank, so that the dissolved gold is uniformly distributed through the liquid.

2nd. 100 tons of ore are milled per day.

3rd. $8.00 is dissolved per ton; 75 per cent in the mill, the balance in the agitators.

4th. The pulp from all thickeners is discharged at a ratio of 1:1 or 50 per cent moisture.

5th. 300 tons of solution is precipitated to a value of $0.02 per ton.

To determine the value of the solution from any thickener, if V, W, X, Y and Z equal the value in dollars per ton of the solution leaving each thickener, we get the following equations, as the same amount of gold and solution will enter and leave each tank:

(1) $400W + (\$6.00 \times 100) = 300V + 100V.$

That is, the gold in W, plus the additional gold assumed to be dissolved in the mill, equals the overflow and underflow of V.

(2) $100V + (\$2.00 \times 100) + 400X = 400W + 100W.$

The $(\$2.00 \times 100)$ represents additional gold dissolved in the agitators.

(3) $100W + 400Y = 400X + 100X.$

(4) $100X + 100Z + (300 \times \$0.02) = 400Y + 100Y.$

(5) $100Y + 100$ water (no value) $= 100Z + 100Z.$

In No. 4 the $0.02 represents the value of the precipitated solution returned to Y.

No. 5, representing a simple dilution with water, means that Z will have one-half the value of Y.

Solving these equations, we get the following values: $V = 2.656$, $W = 1.156$, $X = 0.286$, $Y = 0.076$, $Z = 0.038$, which may be checked as follows:

The gold precipitated.	$(\$2.656 - \$0.02) \times 300$	= $796.80
Lost in tailings	$(\$0.038 \times 100)$	= 3.80
Total		= $800.60
Total assumed dissolved	$(10 \times \$8.00)$	= 800.00
Discrepancy due to decimals		.60

From the above we deduce:

Assay value of solution precipitated	= $2.656
Dissolved loss per ton solution	.038
Dissolved loss per ton ore	.038
Percentage dissolved gold recovered	99.6

Similar calculations have shown that if one thickener is omitted from the flow sheet and no other conditions are changed the dissolved loss is increased to $0.133. Using the same four thickeners and precipitating 400 tons, instead of 300, the loss is cut to $0.08, while if the pulp can be discharged with 60 tons of solution, instead of 100, making it contain 37 per cent moisture, the amount precipitated can be reduced to 240 tons and the loss will only be $0.76 per ton of ore, although the solution precipitated will assay $3.321.

I should explain here that the reason the precipitated solution is added at Y, instead of Z, where it would obviously be more effective in increasing the extraction of gold, is that we have also a mechanical loss of cyanide to contend with. The 100 tons of water which can be added at Z to replace the liquid discharged with the tails reduces the strength of the solution lost to one-half when added to 100 tons of cyanide solution, whereas if added to 400 tons of solution it would reduce it only to four-fifths. A further saving in cyanide can be made by adding the barren solution at X, but this usually means adding an additional thickener on account of excessive gold losses.

It will be noted from these figures that the loss in gold can be regulated at will by increasing the solution

precipitated or the number of thickeners in the series, and also that pulp settling to 30-40 per cent moisture can be treated much more efficiently than pulp settling to 50-60 per cent. If pulp cannot be settled to 50 per cent or thicker it will usually be profitable to use a filter merely for dewatering at the end of the series.

DETAILS OF PLANT

The flow sheet shown, with what has already been said about Dorr thickeners, will give a clear idea of the construction of a continuous counter-current decantation plant.

The tanks in the series are either arranged on a level, in which case both the overflow and underflow must be elevated before being transferred into the next tank or in a series of steps so that the overflow goes by gravity from tank to tank, and only the smaller quantity of underflow is raised each time. Each method has its advantages.

The transfer of pulp is preferably done by a diaphragm or other pump of fixed displacement, as thereby a certain amount of automatic regulation is obtained.

Storage Tanks.—The more a flow sheet and the actual conditions of mill operations are studied the less additional storage capacity is felt necessary.

FIG. 10—DORR THICKENER INSTALLED IN A 130-FOOT DIAMETER TANK BY THE ARIZONA COPPER COMPANY

RESULTS

I realize that details of the technical results obtained in cyaniding will not be of great interest to chemical engineers, so will only say that when working on a hard, quick-settling ore ground to pass an 80-mesh assayer's screen or finer, which can be settled to a thick product containing 35 per cent to 50 per cent moisture, it has proved a most efficient means for the recovery of dissolved gold and silver from the pulp.

Compared with the usual filtration methods it has shown lower operating costs in spite of a higher mechanical loss in cyanide, and a higher recovery due to a lower loss of dissolved values and often to an additional extraction being made that could not be made commercially by direct agitation.

The following quotation from an article on "Continuous Counter-Current Decantation" in the *Engineering and Mining Journal* of October 31, 1914, sums up the conclusions reached at the Gold Road Mill, where continuous counter-current decantation was installed to replace a vacuum plant:

"The operators state that the principal disadvantage they found with the vacuum-filtration system upon their ores was that it was almost impossible to wash satisfactorily the cakes on the leaves. Cakes of uniform resistance could not be formed. They would crack badly and large sections would fall from them, making satisfactory washing impossible. Besides, the expense of labor, repairs and power is considerably more than is necessary in following the counter-current decantation system. They find practically no difference between the two systems in the amount of cyanide and lime consumed, perhaps a slightly greater quantity, amounting to about 0.1 lb. of cyanide, is being consumed in the decantation system.

"An advantage found with counter-current decantation is that the dissolution of gold is so perfect, due to the longer contact between the solutions and the pulp. The difference, considering all things, between leaf filtration and counter-current decantation, is at least 60 cents per ton of ore treated in favor of the latter."

This figure is higher than could be expected under usual conditions, but we have had definite statements of savings from the other plants that have changed as well. Information I have received from a number of plants operating indicate that on quick-settling ore from which $5.00 to $20.00 is recovered the mechanical loss in gold varies between 4 and 10 cents per ton of ore.

GENERAL CONSIDERATIONS—DISSOLUTION AND RECOVERY

From the nature of the process it is apparent that its use for dissolution is antagonistic to its use for recovery of the dissolved material, and although some have proposed the alternation of agitators and thickeners, I have always advocated where a high per cent of recovery in a concentrated form was required, as in cyaniding, all dissolution possible should be made ahead of the system. In other cases, as that described by Dr. Gahl, where it was essential to make the dissolution in stages so as to end with a nearly neutralized liquid and have the copper pulp when nearly finished meet fresh acid, it is, of course, essential, but calls for one series on dissolution and another on washing.

SCALE OF OPERATIONS

It will be seen that any continuous method of treatment of materials has greater relative advantages with an increase in size of operations and a continuous counter-current decantation plant with 50-ft. tanks will require no more labor, and, in fact, less than one with 10-ft. tanks, although it will have 25 times the capacity. As the actual labor cost for operating a series of thickeners is less than one man a shift, it will be seen that

if any washing or leaching operation is requiring the full time of one or more men this method can be considered if other conditions are favorable.

OTHER APPLICATIONS

Fig. 12 is intended to show a copper problem which I think will correspond to many problems that may occur in chemical industries, namely, the complete washing of finely suspended solids and the obtaining of the dissolved material in as concentrated a form as possible from which it is to be recovered by evaporation or complete precipitation, or by any other method, so that none of the liquid has to be returned to the system, as in cyaniding.

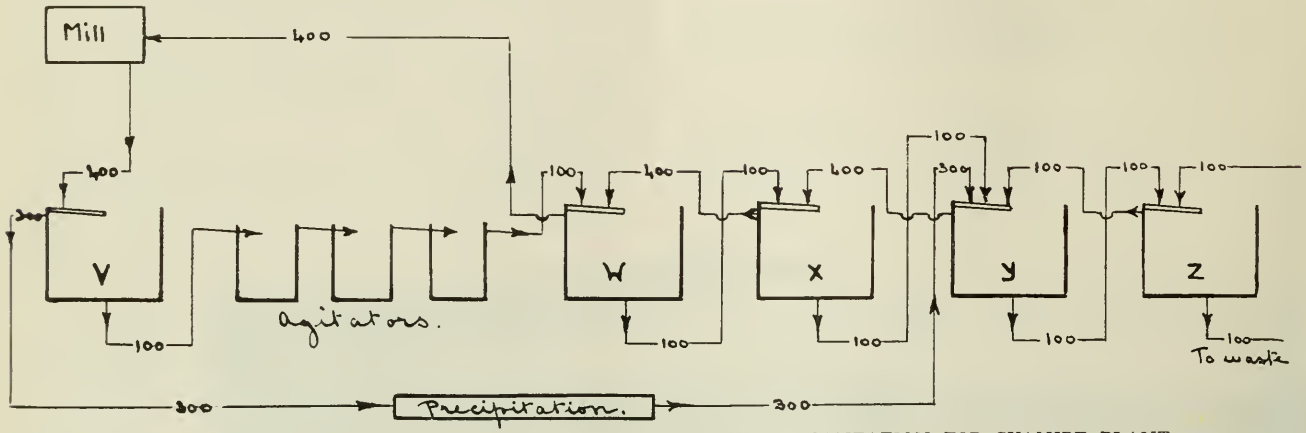


FIG. 11—EXAMPLE OF CONTINUOUS COUNTER-CURRENT DECANTATION FOR CYANIDE PLANT

CONDITIONS ASSUMED

(*a*) 100 tons of oxidized copper ore slimes treated per day.

(*b*) Slimes contain 2 per cent of soluble copper or 40 lbs. of copper per ton.

(*c*) Pulp is discharged from all thickeners with 41.2 per cent moisture.

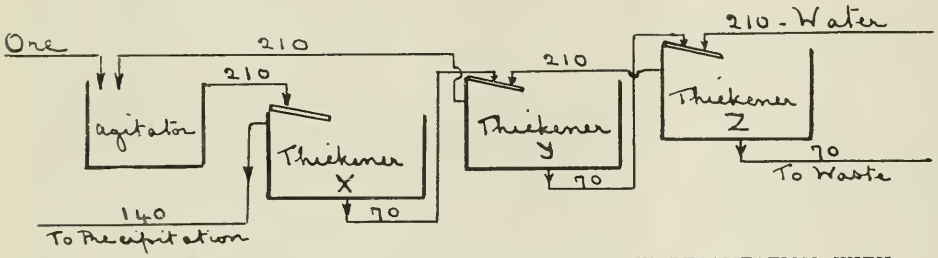


FIG. 12—EXAMPLE OF CONTINUOUS COUNTER-CURRENT DECANTATION WITH WASHING LIQUID NOT REUSED

Figures in Fig. 12 refer to solution tonnages.

(*d*) Inflow to each thickener is thoroughly mixed before entering same.

(*e*) 210 tons of wash water added to thickener "Z." The total overflow from thickener "X," 140 tons, sent to precipitation, and 70 tons sent to waste with the discharged residues from thickener "Z."

(*f*) Let X, Y and Z represent the pounds of copper per ton of solution discharged from the respective thickeners.

If we equate the inflow and outflow of each thickener in terms of tonnage and copper contents we have:

(1) $70X + 140X = 210Y + (100 \times 40)$ pounds
(2) $70Y + 210Y = 70X + 210Z$
(3) $70Z + 210Z = 70Y + 210$ tons of water.

Simplifying and solving we obtain:

X = 27.5132 lbs. copper per ton of solution.
Y = 8.4656 lbs. copper per ton of solution.
Z = 2.7164 lbs. copper per ton of solution.

From the above the following results are deduced:

1. Overflow to be precipitated, *i.e.*, X, contains 1.37 per cent copper, or 27.5 lbs. per ton of solution.
2. Solution wasted with the residues, *i.e.*, Z, contains 0.13 per cent copper, or 2.7 lbs. per ton of solution.
3. Copper sent to precipitation = 96.3 per cent of that dissolved.
4. Pounds of copper lost per ton of slimes = 1.48 lbs.

Varying the number of thickeners used and solution tonnage sent to precipitation, and assuming conditions *a*, *b*, *c* and *d* remain constant, we obtain the following results given in Table III.

It is apparent from this that the enriched solutions, which contain 96.3 per cent of the soluble copper, will carry 1.37 per cent copper per ton, and that you get no weak liquors at all for further handling. The additional tabulations show the results of changing various factors. You will see from this that precipitating 140 tons of solution, but adding a fourth thickener, increases the percentage recovered from 96.3 per cent to 98.8 per cent, with an enrichment of the solution from 1.37 per cent to 1.41 per cent. Precipitating 210 tons of solution, on the other hand, shows a solution to be precipitated carrying 0.93 per cent copper with three thickeners and 0.94 per cent with four thickeners, while the percentage of recovery is 98.5 per cent and 99.6 per cent. In other words, it is easy to see that by using the proper number of thickeners you can make practically any recovery desired and get any concentration you wish.

This method could be applied as readily to the manufacture of caustic from soda ash and lime, and I can say that a plant to use it to some extent has been purchased abroad, but its installation has been delayed by

TABLE III

Number of thickeners used	3		4		3		4	
Tons of solution sent to precipitation	140		140		210		210	
	Lbs. per ton.	Per cent.	Lbs. per ton.	Per cent.	Lbs. per ton.	Per cent.	Lbs. per ton.	Per cent.
Copper in the solution for precipitation	27.5	1.37	28.2	1.41	18.7	0.93	18.0	0.94
Copper in the solution wasted with the residues	2.7	0.13	0.7	0.03	0.9	0.04	0.2	0.01
Lbs. of dissolved copper lost per ton of slimes	1.48		0.49		0.63		0.16	
Per cent. of dissolved copper sent to precipitation	96.3		98.8		98.5		99.6	

the war. As the reaction between the soda and the lime requires a definite time it is possible that it might be necessary to do it in charges, but the same was believed true in cyaniding until it was demonstrated that continuous agitation with a series of agitators was better.

THE DORR AGITATOR

This machine, Fig. 13, was designed by me in 1910, but did not come into actual use until 1912, when about a half dozen machines were put out for trial purposes on a working scale at several different plants. The results obtained were so good that last year many more were installed in this country and abroad. During 1914, although mining in general has been very quiet, the use of them has increased greatly and from all installations made we have had nothing but satisfactory reports.

The illustration will give a good idea of the machine, which is very much like the Dorr thickener, the central shaft being replaced by a pipe, at the top of which distributing launders are arranged to distribute the pulp, which is raised through the pipe by means of air.

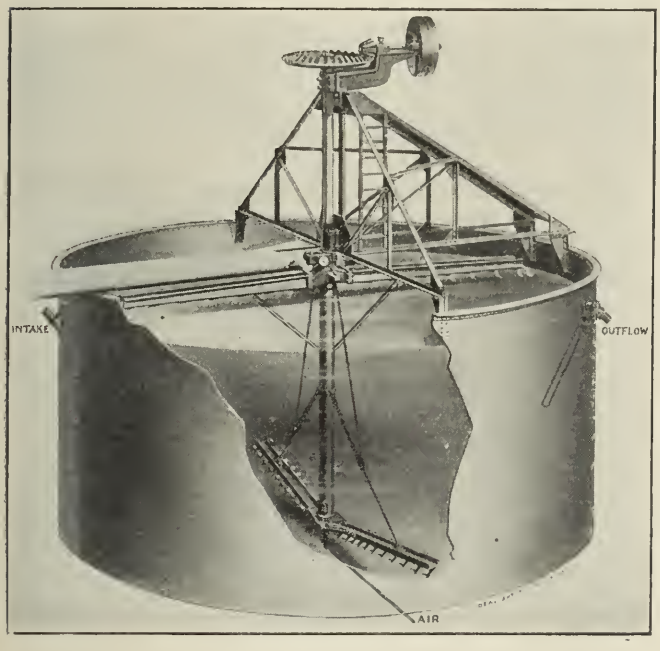


FIG. 13—DORR AGITATOR

A worm and sheaves provide means for raising or lowering the hinged arms at will.

In cyanide metallurgy mechanical sweeps in flat-bottomed tanks were first used for agitating the pulp, but the great difficulty experienced in most cases with these, including breakages and the power required, made the use of a high cone tank with a central air lift seem most attractive, and when it was introduced into this country and Mexico from Australia a very large percentage of the mills installed it.

At this time agitation was done in charges, but when continuous agitation became the established practice a few years ago it was found that there was a great tendency for the coarser material in the pulp being agitated to build up on the sides of the 60° cones used so that eventually the major portion of the agitating area became filled up with solids and the agitation only took place in a small cylinder in the center. It was also found necessary to give a much more violent agitation than the chemical treatment of the ore required in order to keep the pulp in suspension as much as possible.

The Dorr agitator, by the use of mechanical arms with the thickener plows on, which prevents settling of solids and brings the material from the bottom to the central uplift pipe, allows the regulation of the intensity of the agitation given to suit the chemical need of the ore and not the necessity for keeping everything in suspension.

EFFICIENCY

The value of an agitator depends on the cost of making the maximum economic extraction by its use. This will be determined by its cost of agitation per ton per hour and the time required to obtain dissolution.

All the data I have been able to obtain indicate that the cost of agitation per hour is extremely low. Extraction tests that have been made indicate that the rate of dissolution on both gold and silver ores in Dorr agitators, with a uniform although less violent agitation, is at least as rapid as in any other agitators with which it has been compared.

The most favorable conditions for the dissolution of gold and silver in cyanide solution vary with each ore treated. The maintenance of an excess of dissolved oxygen throughout the whole mass of pulp and the free movement of all particles of solids in the liquid immediately adjacent seem to be the only conditions that can be generally specified.

Definite work both in milling and the laboratory indicate that many ores will give a more rapid extraction and allow the use of a weaker solution when agitated as a dilute pulp of 3 to 1 or 4 to 1, and also cause less chemical consumption of cyanide.

The Dorr agitator, with its combination of air and mechanical agitation, gives a flexibility that is apparent, and it insures keeping all the solids in suspension all the time, whether the pulp is subjected to a gentle or a violent movement. This is essential especially in continuous agitation.

SELECTIVE AGITATION

The question of selective agitation was discussed by Mark R. Lamb.* As used here the expression is taken to mean continuous agitation under conditions which cause the coarser particles of the ore to remain in the agitator longer than the average time of treatment and thus give them the longer exposure they may require to obtain the best extraction.

This can be accomplished readily with the Dorr agitator by agitating at a dilution which allows the coarser material to classify out and discharging the raised pulp near the center while the outflow is taken from near the periphery. It will be seen that if a segregation takes place and the agitator is fed a pulp carrying 10 per cent plus 100 mesh, the discharge may be only 5 per cent plus 100 mesh at first. With twice as much inflow as outflow of 100-mesh material it will concentrate in the agitator while gradually increasing in the outflow until an equilibrium may be reached in which the feed and discharge will both be 10 per cent, and the average pulp in the tank 20 per cent, so that the exposure of coarse sand would be approximately double the average. While this is theoretical, enough work has been done to indicate that the idea can be put to practical use.

Dorr agitators have been installed in tanks of various sizes, the largest being those in use at the Desert Mill at Tonopah, Nevada, in tanks 36 ft. in diameter by 20 ft. deep. The company estimates that the total power required to operate one of these large machines, including mechanical horse power and the air required for maintaining agitation, is not over 5 hp., so you will see that it is extremely small. A recent measurement in a 20-ft. by 12-ft. agitator showed that 10 cu. ft.

*Transactions, American Institute Mining Engineers, vol. XL, p. 775 (1909).

of free air at 15 lb. pressure was all that was needed.

The application of Dorr agitators in the chemical industry has not been investigated to any extent, but it would seem that with finely divided materials from which it is desired to dissolve one constituent that they should perform as useful a function as they are now doing in metallurgy.

ACID-PROOF MACHINERY

As all the submerged portions of classifiers, thickeners and agitators have no reciprocal motion, it has not been found difficult to manufacture them so as to resist ordinary acid liquors and acid-proof machines of all three kinds are now in use.

Metal Production Statistics for 1914

The United States Geological Survey has issued preliminary reports on metal production during the past year. The figures are based on exact records for eleven months with careful estimates for December, and are considered very close approximations to the exact figures. From these reports we abstract the salient features.

Iron.—The quantity of iron ore mined in the United States in 1914 is estimated as between 41,000,000 and 42,500,000 long tons. In 1913 there was mined 61,980,437 long tons. The Lake Superior district is estimated to have shown a decrease in production of about 37 per cent, and a production of about 32,915,000 long tons. Prices generally were about 50 to 75 cents per ton lower than in 1913.

Gold.—This industry was prosperous in 1914, and the production is estimated to be about $4,000,000 greater than in 1913, totalling $92,823,500. Alaska output increased about $300,000, and Arizona showed an increase of about $500,000. In California the increase was nearly $700,000 more than in the previous year. The greatest increase was shown in Colorado, amounting to over $1,500,000, coming chiefly from Cripple Creek. Nevada, Idaho and Utah showed small decreases. The rank of the principal gold producing states was California, Colorado, Alaska, Nevada and South Dakota, as in 1913.

Silver.—All records for production of this metal would have been broken in 1914 but for the European war. As it was, the figures indicate an output of 67,929,700 ounces, valued at $37,225,000. Notable increases in production were made in Idaho, California and Arizona; decreases were noted in Montana, Utah, Nevada and Colorado. Nevada, however, still retains first place among silver producers, with Idaho, Montana, Utah and Colorado following in the order given. The general average price for the year was 54.8 cents per ounce, the lowest since 1911.

Copper.—The production of this metal will show a marked decrease compared with that of 1913, due to curtailment inaugurated in August and prevailing throughout the balance of the year. The output of blister and lake copper is estimated at 1,129,000,000 pounds in 1914 as compared with 1,224,484,000 pounds in 1913. Refined copper from foreign and domestic sources is estimated at 1,493,000,000 pounds as against 1,615,067,000 pounds in 1913. The average price for the year was about 13.5 cents per pound, being about 2 cents below the 1913 average. Arizona continued in first place among copper producing states.

Lead.—The production of this metal showed an increase of nearly 100,000 tons over the production of any previous year, and at the same time the average price for the year was the lowest since 1898. The estimated output was 537,079 short tons, worth at the average New York price $41,892,162, compared with 462,460 tons in 1913, worth $40,696,480. For the first time in years there were exports of domestic lead to Europe, the total for the year being estimated at 62,924 short tons, valued at about $4,804,000. The average New York price for the year 1914 was 3.9 cents a pound, compared with 4.4 cents in 1913 and 4.5 cents in 1912.

Tungsten.—The production of tungsten ores is estimated as equivalent to about 990 short tons containing 60 per cent WO_3. This is the smallest output since 1908; in 1913 the production was equivalent to 1537 tons. The production from Boulder county, Colorado, in 1914 was only 466 tons as compared with 953 tons in 1913. Prices ranged from $6.50 to $9 per unit (20 lb.) of WO_3. Of the various tungsten minerals, scheelite was produced in largest quantity, mainly from the Atolia district in the Mohave desert, Calif. Utah, Arizona, Idaho and New Mexico produced small quantities of ore.

Arsenic was produced only as a by-product from lead and copper smelting, but the output was the largest in the history of this country, amounting to 4227 short tons of arsenous oxide, or white arsenic. The 1913 production was only 2513 tons. The chief uses of this product are in glass making, for insecticides, and for killing weeds along railroad tracks.

Portland Cement.—The 1914 output of this material was approximately 88,514,000 barrels, compared with 92,097,131 barrels in 1913. The average value per barrel was probably slightly lower than in 1913.

American Institute of Mining Engineers

The annual meeting of the American Institute of Mining Engineers will be held in the Engineering Societies Building, 29 West 39th Street, New York City, from Monday, February 15th, to and including Wednesday, February 17th.

On Monday, February 15th, at 10 a. m. a meeting will be held on safety and sanitation in mining. In the afternoon two sessions will be held at 2 p. m. in different rooms, one on iron and steel metallurgy, the other on non-metallic minerals (clay, potash, etc.)

On Tuesday, February 16th, at 10 a. m. the annual business meeting will be held, followed by a technical session on various mining, metallurgical, and geological subjects. At 2 p. m. a session on fuels will be held by the committees on petroleum and gas and on coal and coke.

On Wednesday, February 17th, at 10 a. m., a session of non-ferrous metallurgy will be held, and at 2 p. m. a session on electricity in mines and mining.

The annual dinner will be held at the Hotel Astor on Tuesday evening, February 16th.

Inspiration Consolidated Copper Co. is completing its new mill of 10,000 tons daily capacity. Some changes may increase this to twelve or even fifteen thousand tons. Operations are scheduled to begin in April. The estimated cost of copper production is 8½ cents per pound.

The establishment of tin smelting in the United States is one of the possible industrial advantages that can accrue to this country as a result of the European war. Both Bolivian and United States interests might profit by such an arrangement, for Bolivia apparently has supplies of the raw material, and the United States is a large importer and consumer of the metal. Bolivia has been shipping annually from 30,000 to 40,000 tons of tin concentrates to Europe for smelting, while this country imports several times the quantity of tin represented in Bolivia's exports. The metallurgical problem would not be difficult, and the industry could be established here if transportation arrangements can be concluded.

Feldspar as a Possible Source of American Potash*

BY ALLERTON S. CUSHMAN AND GEORGE W COGGESHALL

Two years ago the authors presented a paper before the eighth International Congress of Applied Chemistry, entitled "The Production of Available Potash from the Natural Silicates." This paper** not only presented a general discussion of the work that had been done by a great number of investigators in this field, but also described the results of practical mill runs made by the authors on the large scale of operation. This work had been carried to a successful conclusion as far as the purely chemical engineering side of the problem was concerned, but for reasons which seemed important at that time, no presentation or analysis of cost data was included in the first publication.

As a rule, no worker is in general so much hampered by complex commercial situations in his particular field as the chemical engineer, and this is particularly true with respect to potash problems which rest more or less insecurely upon a network of local, national, and international regulations, economics, and special arrangements. The prices of crude and finished potashes have not in the past rested on the firm basis of cost of production and transportation, modified by the just law of supply and demand, but have been subject to unstable arrangements between national governments and international syndicates. The governments of great nations make bad partners for industrial enterprises in these uncertain days, for they themselves seem to be unable to guarantee the validity of their own contractural agreements. Furthermore, the fixing of prices of a necessity of industry and agriculture by international or national syndicates, by which the interest of the ultimate consumer can not be a prime consideration, is utterly opposed to the present-day tendency in the development of human affairs.

It is one thing to work out a complicated problem in chemical engineering to a successful technical working status on an encouraging basis of costs, but it is quite another thing to assume the responsibility of inducing capital to embark upon an unknown sea of enterprise, especially if this sea is strewn with uncharted rocks and shoals, one, at least, of which may represent the cutting of prices by foreign producers to or below the cost of production for a sufficient period to kill off newborn competition, with the idea of averaging up profits at some future time when the infant industry shall have been effectually strangled. As chemical engineers, however, we may take some comfort for the future from the thought that such premeditated arrangements are becoming unfashionable, if not dangerous.

It is the purpose of this second paper, which may be considered an elaboration of our earlier publication, to present the results of some additional investigation, together with a frank discussion of the cost data involved in the possibility of using American feldspars as a practical source of American potashes. Many workers in this field believe it to be a self-evident fact that the potash alone would not pay the cost of extraction, or, in other words, unless the potash yield was merely a by-product recovery in the manufacture of some valuable main product, the attempt to extract it would be foredoomed to failure. After having made a close study of certain phases of this problem, continuing over a period of many years, we wish to state that in our opinion the economic feasibility of turning to the feldspars as a source of potash is, to say the least, open to debate.

*A paper read before the American Institute of Chemical Engineers, at the Philadelphia meeting on December 2, 1914.

**Abstracted at some length in this journal, November, 1912, p. 727.

Feldspar can be obtained in unlimited quantity favorably situated to our freight and trade routes in this country, which will run quarry-wise 10 per cent in potash (K_2O). The raw material supply, as far as potash ore is concerned, resolves itself, therefore, into a mere question of economical quarrying operations at the usual well-known costs. A comparatively small quarry of such feldspar, containing 1,000,000 cu. ft. of rock, or 100 ft. in cube, would contain 17,000,000 lb. of potash (K_2O) which, if it could be extracted, would be worth even at ante-bellum prices, $700,000. One ton of such an ore would contain 200 lb. of potash, worth, if it could all be extracted, about $7. If we assume, however, that only 75 per cent of it would yield to a chemical engineering process, we still have $5 per ton in value to work for. When we remember that in large-scale operations in the gold-mining industries, quartz that carries no more than $2 per ton in valuable constituents has been profitably worked, the problem need not necessarily frighten us away at the outset.

During the fiscal year ending June 30, 1914, there was imported into the United States $15,000,000 worth of potash salts, kainit, manure salts, muriate of potash, and sulphate of potash. In addition to this, considerable quantities of caustic and carbonate of potash, not included in the later available statistics, were also imported. Of the total, $8,000,000 worth was muriate of potash. The fertilizer industry uses, of course, the larger proportion of these potash importations, the percentage in the last few years being about 85 per cent of the total of muriate of potash imported, there being left about $1,000,000 worth of muriate of potash which was used in industrial work. About half of this total, or $500,000 worth, was used to make caustic potash and carbonate of potash. These are used principally in the soap industries, although a portion is used as a wrapper-tobacco fertilizer and in the manufacture of glass, paper, preparation of colors, in printing, in photography, and in more strictly chemical industries. Some nitrate of potash is manufactured from the chloride. About one-eighth of the muriate is manufactured into chlorate of potash at present, which is largely used in the growing safety-match industry. Potash bichromate uses about one-twentieth of the muriate and this is used in textile and color industries; also in photography.

Before proceeding with an analysis of cost data involved in the possible use of feldspar as a potash ore, it will be well to consider briefly the present sources of the world's supply. The German mines, located principally in the neighborhood of Stassfurt and Magdeburg in Prussian Saxony, have been for the past seventy years the principal source of the world production of the various potassium salts. Prof. O. N. Witt, in an article in the *Chemiker Zeitung* of Oct. 8, 1914, states that borings in Alsace have shown favorable deposits which may prove to be of considerable value. This is interesting news in view of the present doubt as to the future political status of Alsace-Lorraine. The reported discovery of soluble potassium salts in the province of Catalana, Spain, has recently commanded considerable attention and was prominently mentioned in the last annual report of one of our large agricultural chemical companies. According to our latest consular reports under date of Nov. 6, 1914, potash has not been extracted in Spain up to the present time in commercial quantities.* If the Spanish prospects should develop so that they would become a basis of a world trade, they would be welcomed for breaking an existing monopoly, but the source of supply would still be oversea, whereas North American independence in the commodity is highly desirable.

*Consul General Carl Hurst's report in Daily Consular and Trade Reports, Dept. of Commerce, 261, 615.

An American source of potassium salts in any considerable or practical quantity, in spite of much expensive government and private exploration, has not yet been discovered. In the Far West the giant kelps of the Pacific Coast, some of the brines and bitterns of the saline lakes and wells, and the alunite deposits of Utah and Arizona have been proposed and studied as possible sources of potassium compounds. The fact remains, however, that up to the present time three-quarters of all the potassium salts used in agriculture are consumed east of the Allegheny Mountains, by far the greatest quantity going into the three states of North and South Carolina and Georgia.

The reasons for this segregated demand for potash fertilizers are not at once apparent. The authors have made inquiries and have received the following explanations: Cotton, tobacco, intensive orcharding, and truck farming use the largest quantities of artificial fertilizer, while, in addition to this, the educational propaganda of a large Southern agricultural chemical company has demonstrated in its more immediate territory the economy of the proper additions of fertilizer to the land. The great effort which is now being made throughout the country to bring up the yield per acre of all our crops, will in all probability largely increase the use of all fertilizing materials not excepting potash.

It is unlikely that even the Panama Canal under the present tolls system would enable Western potashes to meet European competition on the Eastern seaboard. The fact that the great feldspar dykes of the Appalachian system are in general located in close proximity to the places where potassium salts are in greatest demand makes a special appeal to the chemical engineer. That the growing use for potassium compounds in intensive agriculture and industry will some day make use of the huge quantity locked up in the silicates, seems a safe prophecy. Whether that time has yet arrived is now open to debate.

In this paper, the authors will confine themselves to a discussion of their own methods and chemical engineering experience. There is no intention to ignore the fact that other workers have also proposed or to some extent developed methods for extracting potash from feldspar, either with or without the simultaneous production of valuable by-products. With any or all such methods the authors are not in conflict or debate, the present object being merely to open the subject to discussion along a well-known line. If any other source or method of economically producing American potash is discovered, the authors will follow its development with much interest.

Our previous paper described the working of the process by which the insoluble potash in the feldspar rock was simply converted into the soluble chloride salt, but no separation of this soluble salt from the residual rock was made. The product contained about 4½ per cent water-soluble potash (K_2O) in the form of 7.1 per cent of muriate of potash (KCl), also about 16 per cent of free lime, and the balance was the insoluble mineral material. It was solely a potash-lime fertilizer.

Several hundred tons were produced in regular mill working, and twenty-four hour-a-day runs were made, so that the feasibility of producing this material continuously and regularly was fully demonstrated.

This fertilizer was distributed free of all charges to some score or more of state experiment stations and large growers in many states for field trials as a straight potash-lime fertilizer to be compared with other potash fertilizers, such as wood ashes and various mixtures.

The field results were very favorable, as was to be expected from a material of this composition.

As will be shown later, the cost of production of such a potash fertilizer was low but the added expense of freight charges on a material containing so much inert matter was a serious drawback.

Muriate of potash is the chief potash salt imported into this country. It is sold on the basis of "80 per cent muriate" and usually contains from 70 to 80 per cent KCl, or from 44 to 50 per cent K_2O. This material, having its values in such a small bulk, will bear the cost of freight shipment easily. It is the cheapest potash salt for use as a raw material for chemical manufacturing, and is also well adapted for mixing into general commercial fertilizers. Any potash salt, however, running not less than 17 per cent K_2O (or 26 per cent KCl) is adapted for use in mixed fertilizers. A salt lower than 17 per cent K_2O could only be used where the final K_2O content in the complete fertilizer was to be less than 5 per cent.

Therefore, for the uses of the fertilizer industry, the economical production of any material containing 26 per cent, or higher, of KCl, would find large use, but for the replacement of all or a portion of the one million dollars' worth of concentrated muriate salts used yearly in the United States for chemical manufacturing, it is necessary to produce a salt containing at least about 70 per cent KCl.

Our experimental work was continued with the idea of separating and concentrating the soluble potash salts unlocked by this process, and giving a product so concentrated and pure that it may be used either in making fertilizers or be worked up into other potash compounds for more strictly chemical uses.

The salts are easily leached out from the mass as it comes from the furnaces, and by proper methods a solution of about 10 per cent KCl can be obtained, using the wash liquors for leaching new material. The evaporation of large amounts of water is a serious problem in chemical industry and in this particular case it could not be accomplished cheaply by any of the usual methods of evaporation.

The engineers working on this problem, however, have had considerable experience with methods of evaporation by the direct use of hot waste stack gases. A Porion evaporator, using such gases, is an extremely cheap method of evaporation with furnace gases, provided the material in solution is not harmed by the gases themselves. Even cheaper than this is the method of spraying the liquor through the waste hot gases. Experience with this operation has developed such successful results that it was adopted for this particular work. This use of the hot kiln gases, otherwise wasted, has an added advantage in the potash process from the fact that any volatilized KCl is caught at the stack washer.

The chief technical difficulty in the conversion to KCl was due to the high temperature produced by the powdered coal flame. When the charge, moving down the kiln, is brought up to about 1050 deg. C. the reaction is complete and there is then present in the charge free KCl. If the material is then further heated beyond 1150 deg. C., some of the KCl is volatilized and passes as vapor toward the stack. This final over-heating of the charge, and the volatilization of KCl, may be prevented by the use of a rotating combustion chamber attached to the lower end of the kiln, the charge passing outside of the extremely hot zone which is inside the combustion chamber. This arrangement prevents all over-heating and is so effective that coal itself is dried by this means, in a rotary dryer, with heat from burning powdered coal, the hot zone being confined to the combustion chamber rotating with the kiln. Small burners must be used in such cases, however, and in this potash work it is better to over-heat than under-

heat the charge to obtain the full yield of soluble product. In the mill work described in our previous paper, when no rotating combustion chamber was used, about 16 per cent of the KCl was volatilized during its passage through the hot zone of the kiln. This is now all caught in the stack-washer.

The complete process for the final production from feldspar of potassium chloride salts similar to the concentrated muriates imported from Europe will now be outlined.

A mixture of ground feldspar, containing about 10 per cent of K_2O, and burned limestone, is formed into rounded aggregates or "clumps" about ¼ inch in diameter, by the device already employed, using a solution of calcium chloride for this purpose. Calcium chloride is the by-product of the ammonia-soda alkali process and is the reactive agent in unlocking the potash from the silica. Mixtures of powdered rock and dry calcium chloride are almost impossible to make due to the attraction of the chloride for moisture. Moreover, simple mixing of two materials in the form of fine powders does not give an intimate enough contact of the reacting particles to produce good yields in furnacing operations in which neither of the particles is melted, so as to "wet" the other. In this particular case it was found that a proportion of burned lime mixed with the powdered feldspar will unite with $CaCl_2$ from a solution sprinkled on the powder, to form an oxychloride compound which cements the whole powder into aggregates, giving such a very intimate union of the particles that when heated the reaction yields are high. These aggregates or "clumps" pass directly into the rotary kiln heated either by oil or powdered coal flame. The clumps fall out of the kiln in the same form in which they entered it, but the potash has been converted from the insoluble form into the water-soluble muriate. These red-hot clumps fall into water in leaching vats, where the potassium chloride goes into solution. Several of these leaching vats are used so that the solution of the salt, the leaching, washing, etc., is continually performed. The strong solutions are pumped to the evaporators. The weaker wash liquors are used as leaching liquids for a new lot of processed clumps. The strong liquor containing roughly 10 per cent of KCl will be continuously sprayed down through the hot gases passing out of the kilns to the stacks. This operation is well known and has been studied particularly by our engineers.

The bulk of the water in these solutions is thus evaporated and only very concentrated solutions or sludges are allowed to pass out. These very strong hot liquors are finally dried out in a rotary dryer placed at the head of the lime-burning kiln, using its hot waste gases. The crusts formed are then ground for the market.

The concentrated solution before complete drying contains a small proportion of sodium chloride, corresponding in amount to the proportion of Na_2O in the original feldspar. On a spar running 10 per cent K_2O the Na_2O content has averaged from 1½ to 2 per cent. This would give from the liquors completely dried at once, without any fractional separation of the NaCl, a product having about the following composition: KCl, 70 to 80 per cent; NaCl, 14 to 16 per cent, and the balance a very small amount of lime salts and moisture.

To compare this initial product with imported German muriates, we give in Table I analyses, upon which such salts are usually bought in this country.

It is thus seen that without any attempt at fractional separation, muriate of potash may be made from our American feldspars, equal in character to the usual imported muriates, and that they are as well adapted to be used in commercial mixed fertilizers as those imported.

TABLE I

	70/75 Per Cent Muriate	80/85 Per Cent Muriate
KCl	72.5	83.5
K_2SO_4	1.7	....
$MgSO_4$	0.8	0.4
$MgCl_2$	0.6	0.3
NaCl	21.2	14.5
$CaSO_4$	0.2	....
Insol	0.5	0.2
Water	2.5	1.1
	100.0	100.0

If the hot concentrated liquors are not at once brought to dryness but are given a fractional crystallization treatment, which may be made a continuous operation, whereby most of the NaCl is removed, the KCl crystals then obtained will run pure enough to enable their direct use in the manufacture of chemicals of a high grade of purity. It may be noted that the purchasing analysis of German "90 95 per cent muriates" runs KCl 91.7 per cent and NaCl 7.7 per cent.

However interesting a workable process may be, it must, in order to be successful, produce the final product at a cost less than that of the same material obtained elsewhere. The costs of producing muriate of potash by this process will now be considered somewhat in detail, as we wish to present this subject for the careful consideration of engineers and manufacturing interests in this country.

The plant required is equipped in a general way similarly to a Portland cement mill. There must be rock hoists, trackage, crushers, rolls, rock dryers, grinding mills, a rotary line burner, the "clumpers" and rotary kilns, coal dryer and grinder, besides bins, elevators and conveyors, also leaching vats, tanks for strong liquors and for wash water, pumps, flue arrangements at stack for spraying the liquors, dryers and pulverizer, also air compressor and general power plant, stairs, ladders, handrails, and buildings to house the plant.

Plant costs and annual charges. In order to get the best idea of the various costs, we shall take a concrete example of a plant large enough to handle 300 tons of feldspar per day of 24 hours, this plant being a good-sized commercial undertaking. Such a plant will require three rotary kilns each 100 feet long and from 7 to 8 feet in diameter. We may conveniently divide the plant costs into two parts: (1) Those for equipment usually present in Portland cement mills, and (2) those for special equipment and rearrangements necessary to carry out these potash processes.

(1) The equipment usually found in a cement mill of this size, which would be used in the potash work, is given in Table II.

TABLE II

Quarry hoists, trackage, cars and tools	$4,000
Crushers, rolls, grinding mills	17,140
Rock dryers	4,600
Kilns (3), 7 ft. diam x 100 ft. (to 125 ft.) long	24,000
Air compressor and piping	2,000
Power plant	20,000
Buildings, stairways, handrails, etc	16,000
Miscellaneous equipment (14 per cent)	12,260
Total	$100,000

(2) The special equipment and rearrangements required are itemized in Table III (p. 102).

Now, if 5 per cent interest and 7 per cent depreciation are figured on the first item of $100,000, the yearly

Table III

Belt conveyors	$850
Screw conveyors	1,350
Elevators	4,300
Feeders	600
Chutes and gates	1,140
Bins for dry operations and $CaCl_2$	7,000
Lime kiln and burner	5,000
Oil or coal bins and incidentals	1,000
Clumpers (3)	5,000
Leaching, wash tanks and supports	18,400
Stack alterations and spraying apparatus	1,800
Liquor dryer and stack	2,800
Stack base	400
Disposal system (sludge)	1,000
Pumps and solution piping	3,500
Line shafting, pulleys and foundations	700
Miscellaneous foundations	250
Miscellaneous walkways, etc	600
Contingencies	7,810
	$63,500
Superintendence, etc.	6,500
Total	$70,000

fixed charge is $12,000. It may be possible to lease a cement mill with this equipment for this amount per year, and, if production was desired rather quickly, such a procedure would recommend itself. If the annual charge on this investment is then taken as $12,000, and there is added to it 5 per cent interest and 10 per cent depreciation on the cost of the special equipment, $10,500, we have as the annual charges to plant investment $22,500, or $64.30 per day.

Raw Material and Costs. We think there is a quite general misunderstanding as to the cost of the feldspar for this use. The only considerable use at present for feldspar is for the production of white china and porcelain ware, and for this purpose it must be free from iron-bearing minerals, such as biotite, garnet, hornblende, tourmaline, etc., in order that it will burn white. Therefore, all the feldspar that is put upon the market must be hand picked and iron free, and for such material the prices run from $3 to $5 a ton. For the purpose of producing potash salts from feldspar, it is not at all necessary that the raw feldspar be free from iron. In fact, this process should rightly be called a process for producing potash salts from "feldspathic rock" instead of from "feldspar." Feldspathic rock underlies a large portion of the Appalachian system. Feldspar, free from iron, is a special mineral, occurring in dykes of high purity.

For the purpose of this business, what are now called "feldspar properties" would not necessarily come into consideration at all. The procedure would be to buy by the acre certain lands well located for the purpose and get the feldspathic rock out by open quarrying operations, the costs of which are low and are quite well known. Limestone is quarried rough for about 20 cents per ton and cement rock is quarried in the Lehigh district for about the same cost. We have figured the cost at 50 cents per ton, and have allowed an equal amount for freight, making the cost of crude feldspar at the mill $1 per ton. This low freight charge is made as it would be good policy to have the mill near the feldspar property, and we regard this cost per ton as obtainable. However, we later on give the change in the final cost of the product with change in cost of the raw feldspar. Three hundred tons of feldspar per day at $1 would be $300 per day or $105,000 per year.

The potash is unlocked from its combination as double silicate by the reaction with calcium chloride under heat, the potash and any soda present uniting with the chlorine, forming alkali chlorides. One part of K_2O requires theoretically 1.18 parts of $CaCl_2$, and one part of Na_2O requires 1.79 parts of $CaCl_2$. A feldspar rock containing 10 per cent K_2O and 2 per cent Na_2O will require 15.4 parts of $CaCl_2$. A charge of 300 tons of such feldspar will therefore theoretically require 46.2 tons of actual $CaCl_2$ and in practice some excess of the reactive agent is used. The technical difficulties encountered in making and handling mixtures of feldspar and dry calcium chloride and the means by which these difficulties were overcome, were fully described in our earlier paper. By having a small proportion of free quicklime mixed in with the pulverized feldspar, and by an automatic device by which a strong solution of calcium chloride is continuously sprinkled on a moving layer of the powder, separate aggregates or "clumps" are formed, due to the combination of the free lime with the calcium chloride, with the formation of an oxychloride compound which cements the masses together into an extremely intimate union. The chlorine seems to be in a much more reactive condition in this temporarily formed oxychloride compound than the chlorine in straight calcium chloride, although the higher reaction yields obtained may be due merely to the far more intimate contact of the particles composing the clumps. These clumps are run directly into the rotary kilns.

This automatic method of preparing materials for furnacing operations costs only a few cents per ton and in this and in other furnacing processes it is greatly increasing the reaction yields. It is one of those simple aids to chemical manufacturing procedure which is tending to make continuous operations replace the methods of treating separate batches, and while often increasing the yields, it always decreases the costs.

We shall therefore figure the costs, using for every one hundred parts of feldspar twenty parts each of lime and calcium chloride, or for the plant we are considering, sixty tons of each per day. Provision has been made for a rotary limestone-burning kiln. Limestone can be quarried, brought to the mill and crushed to rather small size for under $1 per ton. At this figure the raw material cost per ton of lime will be $1.70. The cost for burning will be 63 cents per ton, the items of this cost being shown below in the figures for furnacing the feldspar mix. This gives $2.33 as the cost in the mill for a ton of unground lime and the daily charge will be $140 or $49,000 per year. It may be mentioned here that unusual care in burning the limestone is not required, although good burning is advisable.

Calcium chloride is the by-product of the ammonia-soda alkali process and is produced in great quantities in this country. A large portion of the amount produced finds no ready sale. It may be obtained in solid form containing about 75 per cent $CaCl_2$ and the balance water, or in solution in various strengths. The solutions used in our work are quite strong, between 35 and 40 per cent $CaCl_2$, so that the original solutions shipped in tank cars are suitable for the purpose. The questions of freight charges on the water content of solutions and solid cakes as affecting the final cost at the mill of the actual calcium chloride has been gone into quite fully, and we feel justified in stating that in our opinion the net cost per ton of calcium chloride at the mill should not exceed $7.33. The sixty tons required per day will then cost $440 and per year $154,000. However, we later on give the change in the final cost of our product with change in cost of the calcium chloride.

Manufacturing Operations and Costs. Feldspar crushes and grinds more easily than limestone or cement clinker; it breaks easier due to its cleavage planes. It has been found that a high speed mill which will grind 5 tons per hour of crushed limestone so that 65 per cent

will pass a 100-mesh screen, will grind 8 tons of crushed feldspar to the same degree of fineness. The operations of crushing, preliminary grinding and fine grinding of the feldspar and the lime so that over 95 per cent of the mixture will pass a 100-mesh screen will cost about 16 cents per ton for power, 14 cents per ton for labor, and 10 cents per ton miscellaneous expenses, making 40 cents per ton total. The labor charge is for three shifts of six men each. This gives the cost for crushing and grinding the feldspar as $120 per day or $42,000 per year. Using the same figure per ton, the crushing of the limestone and grinding of the burned lime is $24 per day or $8,400 per year.

The power required for the clumping operation is very small for a pump, elevator, feed roll and conveyor. Three shifts of four men each can handle it. The costs are per ton clumped, power 1 cent, labor 8½ cents, miscellaneous 3½ cents, total 13 cents, making a daily charge of $46.80 or $16,380 per year.

The furnacing charges for heating the feldspar clumps are considerably less than those for burning Portland cement, as less heat is required, the maximum temperatures in the kiln being about 1100 deg. C. or 2000 deg. Fahr. In our work with cement kilns it was found necessary to reduce the size of the coal burners, and cut the amount of coal fed in by at least one-third or overheating would result. The coal requirements in burning limestone in rotary kilns show about the same reduction from Portland cement requirements, although a ton of quicklime requires the heat from about 75 lbs. of good coal for the actual decomposition of the limestone from which it is made. We do not know the amount of heat evolved or absorbed in the union of K_2O with the silica and alumina in the formation of feldspar, nor do we know the amount of heat evolved or absorbed when CaO unites with the same substances. The following data, however, is available:

$(K_2 + Cl_2)$ — $(K_2 + O)$ evolves 114,120 gram. calories.
$(Ca + Cl_2)$ — $(Ca + O)$ evolves 38,990 gram. calories.

Using these figures above, in a double decomposition where on the one hand calcium is removed from $CaCl_2$ and unites as CaO with silicates and on the other hand potassium leaves its union as K_2O with silicates and unites with chlorine to form KCl, there is evolved an amount of heat equal to 1440 B.t.u. per pound of K_2O. This means that an amount of heat is evolved in the kiln at the reacting temperature, corresponding to 15.5 lbs. of coal for every ton of the charge heated in this process and by that much decreases the amount of fuel necessary to be burned. Our figures are 300 lbs. of coal per ton of burned clumps, but to this we add 20 per cent for the evaporation of the 17 or 18 per cent of water the original clumps contain. This gives a coal consumption of 360 lbs. per ton, or a cost of 45 cents per ton for fuel. Drying and grinding the coal costs 7 cents per ton of furnace product, power for the kilns 5 cents, a labor charge of three shifts of three burnermen each comes to 7½ cents per ton, and adding 5½ cents for miscellaneous expense gives 70 cents per ton furnacing charges on the 420 tons per day produced by this plant. The daily charge is $294 and for the year $102,900.

The leaching of the furnace product has been done in a small way, but it has not actually been carried out at present upon a large scale, as no plant has had the necessary equipment. A complete equipment has been designed for a mill of the capacity we are considering. Four leaching tanks per kiln, each with a capacity of 2800 cubic feet; one tank for strong liquor for each kiln, with a capacity of 5600 cubic feet; and one common wash water tank with a capacity of 19,600 cubic feet are provided, with all foundations, piping, pumps, walkways, etc. Also a re-arrangement of the usual stacks so that the liquors are sprayed down through the hot kiln gases and in the same direction in which these gases are traveling at the time, dampers, direct by-passes, and a system for disposing of the residual mineral sludges to the dump. The power cost per day figures to $10.80; the labor of three shifts of five men each to $39.00, and adding $10.00 for miscellaneous expenses, the charge to this operation per day would be $59.80 or $20,930 per year. A 10 per cent solution of KCl pumped to the stack evaporators, if concentrated to a 30 per cent solution, will require the evaporation of 10.54 tons of water per hour in the three stacks. If the coal runs 13,000 B.t.u., this means the total heat from 0.91 ton of coal per hour. There will be burned in the kilns 3.15 tons of coal per hour, and it will require only 29 per cent of the heat generated in the kilns to effect this evaporation. This strong hot solution, pumped direct to the final dryer between the lime kiln and its stack, will require the evaporation of 3.7 tons of water per hour, requiring the total heat from 0.317 tons of coal. There will be burned in the lime kiln 0.44 tons of coal an hour or an excess of 40 per cent. Should this not be sufficient to effect the complete drying of the crusts of muriate of potash, and if it was necessary to add 50 per cent to the amount of coal burned, the added cost would be $9.50 per day which would increase the total charges per day only 0.64 per cent.

The totals of the above costs are therefore

	Per Day	Per Year
Overhead expenses on plant.....	$64.30	$22,500
Raw Materials	880.00	308,000
Manufacturing operations	544.60	190,610
Total	$1488.90	$521,110

Product. In our operation of this process in a Portland cement plant, 83.2 per cent of the insoluble K_2O in the feldspar was converted into KCl. This was done in a short kiln only 55 feet long and better results are possible in longer and more efficient kilns. There is little doubt that 80 per cent can be obtained in the plant under discussion. From a rock containing 10 per cent K_2O there would be recovered, therefore, in the final product 24 tons of actual K_2O in the form of 38.03 tons of KCl. This product should be about 80 per cent strength, therefore the actual final product will be 47.54 tons per day or 16,639 tons per year, running 80 per cent KCl and a trifle over 50 per cent K_2O, a material identical with "80 per cent Muriate" imported from Europe.

The cost of this product figures to $31.32 per ton. Table IV gives the costs in cents per pound and in terms of fertilizer units.

TABLE IV

Product—	Per Day	Per Year
(80% KCl = 50.48% K_2O.. ..	47.54 tons	16639 tons
Actual KCl	38.03 "	13310 "
Actual K_2O	24.0 "	8410 "
Cost per ton of product.....		$31.32
Cost per pound of KCl—		
Overhead		0.0845 cents
Raw materials		1.1570 "
Manufacturing		0.7161 "
Total		1.9576 "
Cost per pound of K_2O—		
Overhead		0.1340 cents
Raw materials		1.8333 "
Manufacturing		1.1346 "
Total		3.1019 "
Cost per "Unit" of K_2O.....		62.04 cents

Each change of 50 cents per ton in the cost of the raw feldspar rock changes the final cost of the K_2O in the product 0.3125 cents. Each change in cost of $1.00 per ton in the cost of calcium chloride changes the final cost of the K_2O in the product 0.125 cents.

If 80 per cent muriate of potash has been heretofore used at a cost in this country of $37.50 per ton, there is thus shown a saving by the above process of over $6.00 per ton or 20 per cent profit on the manufacturing cost. All the materials for the operation are to be had in this country, and the costs as established by the first plant would not be increased in the future by any foreign complications. As to whether the German syndicate will continue after the close of the present war, we can only say that it seems probable, as under no conditions now foreseen will the Stassfurt potash deposits be separated from Prussia nor will Prussia be separated from her potash deposits.

A very large production of muriate of potash from American feldspar rock would probably invite price cutting after the war. A reasonably small production, such as outlined in this paper, might supply the requirements of certain industries and still not be a large enough proportion of the whole amount used in this country to warrant a price war. Wise governmental measures might enable even a very large domestic industry to be built up, which would make us independent of foreign materials for this valuable and essential ingredient of our fertilizers. If the crop yields per acre are to be increased in this country, some such independence may be necessary.

The permanent assurance that the fertilizers of this country may be supplied from domestic sources and that miscellaneous industries such as the soap, glass, match, color, photographic and strictly chemical industries using $1,000,000 worth of potash a year can be assured of a constant source of supply would go far to stabilize a great many of our manufacturers and would, by so much, be an item of true progress, as the raw materials are not at the present time used for any useful purpose whatever.

It may be of some interest to record in passing that the present war conditions abroad have caused the market price of muriate of potash to rise. Last week we were quoted this material at about $100 per ton. If a plant of the size we have been describing was put into operation by leasing a cement mill and expending $70,000 on additional equipment, which could be finished in three months' time, and if the muriate of potash was sold at one-half the present quoted prices, or $50 per ton, the profits figure out as $26,300 per month. After three months' operation the plant would have been paid for and at any time afterwards the plant could be scrapped and a good profit still be made on the enterprise.

We have made no attempt to put a value upon the large amount of by-product rock matter. In the plant we have considered, there would be produced, figured on the dry basis, about 370 tons of this residue per day. It would have a composition about as follows:

Silico (SiO_2)	65.8%	
Alumina (Al_2O_3)	17.4%	
Lime (CaO)	13.5%	
Magnesia (MgO)	1.0%	
Potash (K_2O)	1.9%	(?)
Soda (Na_2O)	0.4%	
	100.0%	

Owing to the volatilization of ferric chloride, the material is almost pure white and might find use in the glass, pottery, porcelain or brick industries. It is similar in chemical composition to some clays except that it has a higher content of lime and a considerable proportion of this lime is already combined with the silica. Some use in glazes might be found. Although high in alumina, certain glass products might be made, using it in mixtures, particularly plate glass and some bottle glasses. Its freedom from color is a point in its favor and also the assurance of practically constant composition and physical condition. If 50 cents a ton could be obtained for it after being dried, the income would be about $120 per day. This would reduce the net cost of the 80 per cent muriate product to $28.80 per ton, and the cost of the K_2O to 2.85 cents per pound.

Conclusion. In concluding this paper, the authors wish to record the fact that they are already familiar with many strong arguments which can be used against the advisability of attempting to manufacture potash in the United States.

It is frequently stated that the Stassfurt potashes could be sold in this country for about one-third of the prices which prevailed before the war and still yield profits to the foreign mines. Whether this statement is accurate or not, we have no means of ascertaining, but even if it is nearly true, it clearly proves that the words used in the introduction to this paper were not too emphatic, in which it is pointed out that special interest rather than the cost of production has controlled prices. If potash has any bearing whatever, through intensive agriculture, upon the production and price of food crops, however indirect this bearing may be assumed to be, the control of the product by any single interest is unquestionably hurtful to the best interests of the people of this country.

In the opinion of some more or less well-informed persons, potash is not nearly so important to growing crops as the other principal plant foods, combined nitrogen and phosphates. In other words, there is a tendency in certain quarters to believe that the propaganda in favor of the widespread necessity for potash ir fertilizers has been overdone and that our agriculturalists could rest contented with potash reserves in the soil for many years to come, provided other conditions are properly looked after. However this may be, it is difficult to persuade either the practical grower or the scientific agriculturist that he does not increase his yields and early bearing, by a wise use of potash in one form or another. Up to the present time, the statistics of our average crop yields per acre are not a source of pride to those of us who study such comparative data.

It is the earnest belief of the writers that the American demand for an American source of potash at a fair price will continue to increase in the future. Whether the time has arrived when any progress along this line can be made, still remains in doubt. The foregoing paper has been offered to the Institute with no pretence at settling this important question but merely as a contribution to which we invite the attention and consideration of chemical engineers and others who may be interested.

The Institute of Industrial Research,
Washington, D. C.

The Alaska Gold Mines company has started its new mill, the first unit of 1500 tons daily capacity having been placed in operation in January. It is expected that full capacity of 6000 tons daily will be reached by June. A special meeting of stockholders of the company was held Jan. 21 for the purpose of authorizing an issue of $1,500,000 ten-year, 6 per cent convertible debentures.

The Nipissing Mining Co. shipped from Cobalt during the month of December, 1914, bullion to the value of $535,864. The high-grade mill treated 175 tons of ore and shipped 1,093,510 ounces refined silver.

The Development of Continuous Counter-Current Decantation in Cyanidation of Slime

BY W. J. PENTLAND

Continuous counter-current decantation as applied to the cyanidation of slime from gold and silver ores, offers a simple, economical, and efficient method of treatment. The object of the process is to separate from the slime and recover the solution containing precious metals. The principle of the method, as its name implies, is to effect this separation and recovery by decantation of the valuable solution from settling slime, washing the dissolved metal from the slime by means of a counter-current of water and barren solution, and performing these operations continuously. The process is applied in a series of Dorr continuous thickeners, through which thickened slime flows from head to tail of the system, while washing solutions flow in the opposite direction. The slime becomes gradually impoverished and the solution steadily enriched. A general outline of the system is shown in Fig. 1.

Several years ago the opinion was held by some, and publicly expressed in the technical press, that the application of continuous decantation to the treatment of slime would be a backward step; that displacement by filtration was the logical mode of recovering dissolved metal from ore-pulp; and that dilution by decantation was illogical. Since that time, however, continuous decantation has continued to show economy in practice to such an extent as to render the former contentions untenable.

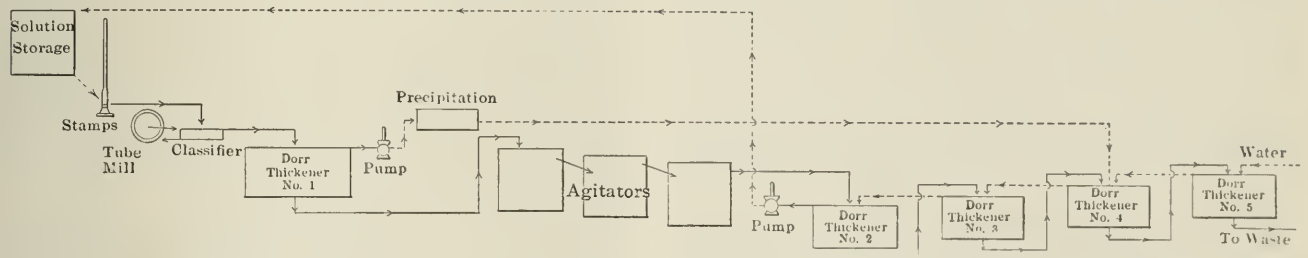


FIG. 1—DIAGRAMMATIC ELEVATION FLOW-SHEET OF CONTINUOUS COUNTER-CURRENT DECANTATION

Positive displacement methods, such as vacuum and pressure filtration, are theoretically ideal. They may even give better metallurgical results than can be obtained by dilution in continuous decantation; but if their economical results are inferior they must give place to more economical methods. As a matter of fact, continuous decantation has shown excellent results both in metallurgical extraction and economy of installation and operation, comparing very favorably with filtration processes.

The general adoption of a metallurgical system does not result from technical perfection alone; it is accomplished by superior economic results measured in dollars and cents. Filtration came into use, not merely because it was technically better than intermittent decantation, but because it was also economically better. It seems not unreasonable to assume that if, at the time operators were beginning to feel that some improvement on intermittent decantation must be developed, more attention had been given to continuous decantation, filters would not have come into such general use for recovering valuable solution, but would have been used mainly as dewaterers.

At the time filters were developed, however, satisfactory slime thickeners had not been produced, and attention was given to filters as offering the best solution of the slime-treatment problem. Subsequent experience with these devices showed that the anticipated displacement of 1 ton of solution with from 0.8 to 1 ton of wash was not obtained, and that in practice from 2 to 2½ tons of wash had to be given, thus producing considerable dilution. Operating cost, when complete washing was accomplished, was too high, and the desire for more economic results caused operators to look about for an improvement on filtration. In the meantime Dorr developed his continuous thickener which lent itself so well to schemes for handling slime continuously that continuous decantation received the impetus necessary to bring it into successful use. It is stated[1] that since 1910, when the first continuous decantation plant using these thickeners was operated, "over twenty plants have been erected or are now being installed to operate by this method."

Some Early Objections to Continuous Decantation

It was probably natural that when the process first came into use, more or less skepticism existed as to its feasibility, and that objections were raised that were due, in some cases, to a misunderstanding of the method. It is true that the process is not of universal application; but while it has its limitations, it is susceptible of a number of variations that make it widely useful.

Some opposition developed through a confusion of continuous decantation with continuous agitation. These are two distinct functions in ore-treatment; and if the ores to be treated vary so widely in character that different periods of agitation are required, the agitating equipment should be designed accordingly. Such provision has always been made for intermittent decantation, and the same allowance must be made in the case of continuous decantation. The troubles and deficiencies of agitation must not be shouldered onto continuous decantation; if the former does not meet the requirements of the ore, the latter cannot rectify the trouble.

Within ten days of the time of writing, I visited a mill where the change from intermittent to continuous decantation is nearing completion. The agitation system is intermittent as before, and designed to meet the requirements of the ore; but a storage or equalizer tank has been placed between agitators and continuous decantation system. This mill has been treating over 300 tons daily and the change has been made without interrupting the regular tonnage. The management expects the remodeled mill to treat a larger tonnage than formerly.

Another point on which some were skeptical was the possibility of classification occurring during the flow of pulp through the successive thickeners, whereby heavier or larger particles of ore would become segregated. We have found, however, that where the ore is homogeneous, and the crushing and grinding departments yield a uniformly fine product, noticeable differences do not appear in screen analyses of the pulp at different points in the system.

An exception to this condition may occur when the ore

[1] The Dorr Hydrometallurgical Apparatus. By John V. N. Dorr. *Bulletin* A. I. M. E., Aug., 1914, p. 2063.

contains two widely different gangue rocks, such as quartz and clay. A pulp of such material cannot be thickened beyond a certain point, and any attempt to do so will result in discharging the quartz from the thickeners faster than the clay, leaving the latter to accumulate until it appears in the overflow. The correct density for such a pulp must be determined by experiment in order to avoid this segregation. Should slime appear in the overflow of the thickener, the quantity of moisture in the discharge must be increased until normal conditions return.

Another objection, which probably is more valid than those mentioned, is raised in connection with ores of such physical characteristics that they do not settle readily, requiring a large unit settling area, and discharging from the thickeners with too high a percentage of moisture. In a plant of large capacity treating such an ore as this, the required plant for continuous decantation might be too extensive, necessitating buildings of large area. Under such conditions, filtration might prove preferable, perhaps following decantation in one or two stages. The decanting process would even then serve to reduce the value of slime sent to the filters, and hence minimize the loss of dissolved metal in the filter cake.

No Serious Trouble from Occasional Interruptions

When a sudden and unexpected interruption of power service occurs in slime plants, a charge tends to settle and pack in the bottom of the tanks. With Dorr thickeners, however, no serious difficulty is encountered in bringing the charge into circulation again. At the moment of stopping, the rabble arms can be raised above their usual position so that they do not become packed in settled slime. On starting again, the arms are gradually lowered to their normal position, disintegrating the settled mass and moving it to the point of discharge.

With intermittent decantation in ordinary vats the conditions are not so favorable. Sand and slime pack in the bottom and cause much trouble in resuming operation. At one intermittent decantation plant of cone-bottom tanks, I attempted to secure washing of the pulp by discharging it into these tanks previously filled with the wash solution. The desired washing was accomplished, but the excessive dilution allowed the sandy part of the pulp to settle rapidly and plug the discharge. This difficulty was finally overcome by leaving a part of the previous charge in the tank, which sufficed to prevent rapid settlement of the sand.

In continuous decantation with Dorr thickeners the cost for repairs, power, and labor is much lower than for intermittent decantation. Dorr states[2] that "many machines (thickeners) are running to-day that have not cost a cent for several years." Power cost is low, ½ hp being sufficient allowance to make for each thickener when several are driven from the same lineshaft. In fact, the power required for the entire plant below the tube-mills is surprisingly small. In the new mill for the Rochester Mines Company, at Rochester, Nev., a 15-hp motor is provided to run three agitators, six thickeners and the necessary solution and slime pumps and shafting.[3] As for labor, "at the Anaconda four men per shift are more than enough to care for 160 tanks thickening 26,000,000 gal. per day, containing 2500 tons of solids."[4] When these conditions are compared with the labor of attendants in an intermittent decantation plant, lowering and raising decanting pipes, starting and stopping pumps and agitators, recording the progress of many charges through the plant, sampling and calculating tonnage on each charge, etc., some idea of the advantages of the continuous system will become apparent.

As for comparative capacities, the continuous system will handle from 40 per cent to 60 per cent more ore than can be put through an intermittent system, and do it cheaper and better. Under continuous decantation every tank is in active service all the time, while with intermittent conditions the tanks are working actively only about half time.

Simplicity of Arrangement and Operation

For simplicity of arrangement and ease of operation it would be difficult to excel a properly designed continuous decantation plant. All of the thickeners and agitators can be placed on one floor below the level of tube-mill discharge. Slight differences in the level of thickeners permit gravity flow of wash solutions. When diaphragm pumps are used for the transfer of pulp from one thickener to another they are placed at the top of the thickeners, and as a result the flow of all slime and solution can be observed from one floor at the average level of the top of the thickeners.

Concentration of plant in a small area, when favored with facility of operation, makes easier conditions for the attendants who can then be expected to perform their work properly. Too often plants are built to satisfy only the technical plans in view, taking it for granted that the attendants can always find a way to do their work regardless of plant arrangement. So they can; but it takes more of them to do the work and they do it less efficiently than in a well-designed plant. When, with concentration of plant and facility of operation, we also have simplicity of arrangement we are indeed favored. These are all obtained in properly designed continuous decantation as developed at this time. Once the rate of flow of pulp and solution is established, attention to the plant becomes simple routine.

A number of valuable plant accessories have been developed to aid the operator in maintaining uniform conditions. Diaphragm pumps furnish a means of moving pulp with positive measurement; the mechanism gives little trouble or wear. Overload alarms on thickeners, with electric bell attachment and graphic indicator, provide a check against carelessness and possible accident from too dense pulps. In short a continuous decantation plant is as near fool-proof as could be desired.

Gravity Flow of Wash Solutions

The general arrangement of a continuous decantation system with relation to the other departments of a mill, appears in Fig. 1, showing the relative levels of the different units. The five thickeners and three agitators can be arranged on one floor of the mill. Diaphragm pumps, not shown, are used to raise the thickened pulp from thickener No. 1 to the series of agitators, and from thickener No. 2 to No. 3, 3 to 4, and 4 to 5. Solution pumps elevate the overflow from thickener No. 1 to precipitation and from No. 2 to storage. Otherwise the flow of solution is by gravity. The precipitating apparatus is placed high enough to allow barren solution to flow by gravity to the desired point in the system, and the last four thickeners have sufficient difference in level, say, 2 ft., to permit gravity flow in countercurrent to the slime.

At first sight one might think that as it is easier to maintain solution pumps than slime pumps in good order, it would be more logical to arrange a gravity flow of pulp than of solution. There are a number of serious objections to such a plan. In the first place, the

[2] Ibid.
[3] This journal, November, 1914, p. 677.
[4] *Bulletin* A. I. M. E., August, 1914, p. 2060.

positive measured flow of pulp of uniform density is of great importance, and we cannot be assured of this by gravity flow through a fixed orifice. But if we transfer pulp by a mechanical device, such as a diaphragm pump, which at each stroke transfers a definite volume of pulp, we can easily maintain uniformity in the density of pulp transferred. If, temporarily, an undesirable change occurs in the density of the pulp, the pump will correct the condition; if the pulp is too thin, a larger relative volume of solution will be withdrawn at each stroke and *vice versa*. Such conditions cannot be obtained by means of a spigot discharge controlled by a valve. Furthermore, we have long since learned that the orifice of a valve plugs so easily as to condemn it for regulating the flow of pulp.

Another objection to gravity flow of slime through the system is found in the loss of mill-head that would result from the necessary arrangement of thickeners. With gravity flow of solution, the difference in level between thickeners is only about 2 ft., whereas an arrangement providing for gravity flow of pulp would require a difference in level between thickeners practically equal to the depth of the tank plus space for pipe and valve clearance. Thus the plant would resolve itself into a number of floors and the arrangement for driving the thickeners would be complicated. Furthermore, the power required probably would be greater, as approximately 1 hp would have to be provided for pumping solutions from tank to tank, as against 1/3 hp for elevating pulp by diaphragm pumps. In short, the arrangement of thickeners for gravity flow of solution gives us many advantages in construction, arrangement and power, and the elevation of pulp by diaphragm pumps corrects irregularities in density of the flow.

The air-lift can be used instead of the diaphragm pump for transferal, but it is usually not so satisfactory. It is especially recommended that the thickeners be equipped with overload alarms on the driving mechanism, and that the capacity of the lift be closely adjusted to the average flow of pulp.

The flow-sheet in Fig. 1 shows that the overflow from thickener No. 1 is precipitated. It is usually found unnecessary to precipitate this entire overflow in order to reduce the value of circulating solution. Any excess above the quantity precipitated can be returned to the mill-solution storage tank. In order to send a constant quantity of solution to precipitation, the overflow of No. 1 can pass to a receiving tank provided with a fixed orifice and overflow launder. As this tank will always be full, there will be a steady flow to the precipitation plant and thence to thickener No. 4. The excess solution overflowing the receiving tank can be combined with the overflow from thickener No. 2.

I recently visited a 100-ton mill using the continuous system, in which there were no sump or storage tanks. When operations were temporarily interrupted, the outlets of the overflow launder of the thickeners were plugged, thereby providing 8 in. or 9 in. additional depth in the thickeners for the storage of circulating solution until operations could be resumed.

Thorough Mixing of Pulp and Wash-Solution Necessary

A requirement of continuous counter-current decantation that must not be overlooked is the thorough mixing of wash-solution and pulp entering the thickeners. This can be accomplished by placing staggered baffles in the receiving launder and giving the latter sufficient fall from the periphery of the tank to the center to carry the mixed pulp through the tortuous path defined by the baffles.

From the launder the pulp can be received in a suspended central well in the form of a cylinder surrounding the vertical driving shaft of the thickener. The well can extend from 18 in. to 3 ft. below the level of solution in the tank and perhaps 1 ft. above. A suitable diameter for the cylinder would be also from 18 in. to 3 ft., depending on size of tank and dilution of pulp. Floating loosely within the cylinder, a wooden baffle can be placed to break the force of the incoming stream of slime solution. The baffle can be made in two pieces for convenience in case of removal, and it has an opening through which the vertical shaft passes. This device will reduce any tendency to form currents in the settling slime and will be an aid to quiet settlement, especially if the capacity of the thickener is being pressed to the maximum.

In case the thickeners are all on the same level, as for example in a remodeled plant, it may be necessary to make special provision for the mixing of pulp and wash-solution, as this cannot be done in launders.

To digress a moment, I see no particular advantage in the circular overflow launder that accompanies Dorr thickeners. This launder is expensive to construct and difficult to level, and it has but one side available to receive solution. Instead of this circular launder I suggest one of hexagonal form. For example, in a thickener of 24 ft. diameter, a hexagonal launder constructed of six 12-ft. sections could be supported in the tank at six points equidistant on the inner periphery. This launder would measure nearly 72 lin. ft. around its outer edge and nearly 66 lin. ft. on the inner, or a total of 138 lin. ft. available to receive overflow. A circular launder for the same thickener would measure about 75 lin. ft., and have but one side available.

Variations of Continuous Decantation

An important feature of the continuous decantation process as developed by Dorr is that, from data of tests on an ore, the probable results in practice are susceptible of close calculation in advance; and the counter-current flow of solution can be varied to give the most economic results as regards loss of dissolved metal and mechanical loss of cyanide in the tailing. Different ores present individual problems; but when the mechanical and chemical requirements of an ore are known, the calculation of results gives an accurate forecast of what may be expected in practice.

To obtain the most economical results, the counter-current flow of solution can be varied, but the flow of thickened pulp is always in a regular and unbroken line from head to tail of the system.

From what has been presented it would seem that we may anticipate a wider use of this method of cyaniding slime as its advantages become better known. In some cases it may be wise to meet special conditions by adding a filter to the system, to reduce dissolved metal loss or mechanical loss of cyanide, or to dewater tailings for stacking or conservation of water. No attempt should be made to impose on continuous decantation any duties that it cannot perform economically; but on the other hand, it should receive careful consideration wherever it seems applicable. Past progress in its adoption has been conservative, and each new installation has increased our knowledge of its possibilities.

Guadalajara, Jal., Mexico.

Aluminium alloys of different types have been patented by W. A. McAdams, of Bay Shore, N. Y. One is a soft alloy, suitable for making metal foil. It contains 100 parts aluminium, 30 cadmium and 5 tin. Another, designed to make cast objects that will not tarnish, contains 100 parts aluminium, 20 silver, 10 zinc and 5 copper. The third is a casting alloy containing 100 parts aluminium, 18 copper, 5 zinc and 3 antimony.

Limitations of the Electric Furnace in the Manufacture of Steel Castings

BY G. MUNTZ

In the September issue of *Metallurgical and Chemical Engineering* Mr. Ivar Rennerfelt takes exception to certain statements made by the writer in his article published in the June issue of the same magazine, under the heading of "Tropenas Converters vs. Electric Furnaces for the Manufacture of Steel Castings."

From the arguments advanced it is clear that Mr. Rennerfelt has misunderstood the purpose of the comparison made between the converter and electric processes in general. The writer's object in writing his first article was not to prove that metallurgically the converter was superior to the electric furnace, as doing so would be defending a paradox; we only tried to bring out the fact that the electric furnace represents the ideal means of producing ideal steel, but that the great problem is to determine whether or not its use is commercially possible. Cases such as this are not uncommon in any industry and the best example can be put in the shape of a question, namely, "Why is diamond not superseding tool steel?" The answer is one of commercial impossibility. Diamond represents an ideal, which, like others, cannot be used commercially.

Among various problems, none presents more difficulty of solution than that faced by the foundryman, who, at the crossroads of progress, must choose between the newer and yet uncertain melting method, and the old, reliable and approved methods such as the crucible, the Tropenas converter and the open-hearth furnace.

It is clear, however, that any method used in the foundry must be able to compete with other processes, and it might, therefore, prove interesting to discuss the various points brought up by Mr. Rennerfelt.

Economy

Authorities in the United States agree that although cheap energy is one of the main factors in the economical production of electric steel, it is not of such great importance. W. L. Morrison, before the convention of the American Foundrymen's Association last September, stated:

"Steel can be melted and refined in the electric furnace for from $27 to $35 per ton in the ladle, depending on the power cost, cost of materials and the care of the melter. The electric furnace to-day is somewhat overrated by claims that it is especially adapted to all foundry use; that its operation is very simple and easily mastered, and that the hottest kind of metal is obtained, so that low-carbon steels can be poured in the thinnest sections. All these statements are more or less true, but should be investigated by the foundryman, so as to avoid disappointment after installation.

"There are some installations of electric furnaces which have been made during the past two years, which did not come up to the expectations of the foundryman, and were either abandoned or operated in a half-hearted way. An electric furnace installed with the idea that one heat a day will pay its way is disastrous to the foundry. The electric furnace, while adapted to foundry work under certain conditions, should not be considered as an ordinary piece of apparatus. It is very delicate or at least certain parts are, as one finds out in practice. A careless melter can add $5 to $15 to the cost of a heat from electrode breakage by neglecting to raise his electrodes during the removal of slag, or when charging the furnace.

"In the charging of the furnace a certain amount of care must be exercised to insure prompt electrical contact and smooth working of the electrodes. I think the electric furnace involves more good common sense and observation than any of the well-known methods of producing steel. It is very easy to lose an hour or even three hours by poor electrical contact at the offset, due to either poor charging or poor selection of scrap. Those who have had practical experience with the furnace know how aggravating a poor electrical contact is; on the other hand, a short circuit the moment the arc is made and subsequent surges of current are readily overcome by placing a little slag around the electrodes.

"The operation of the furnace and the reactions taking place appear so simple that the ordinary spectator is apt to be misled."

E. B. Clark, who probably has had more experience than any other in this country in the use of electric furnaces for manufacturing steel castings, stated in a lecture before the American Electrochemical Society last April that:

"The cost of production is the final answer from a commercial standpoint, and this depends not only upon the market for the intended output, but upon the available supply of steel-making materials, and upon the availability of a satisfactory and sufficiently cheap source of electrical power. In passing it might be observed that this question of electric power supply is generally not so serious as might at first appear. In the first place, there are many locations where a sufficient amount of fairly cheap electric power may be purchased, and in the second place, the item of power is not often of supreme importance.

"There are other elements entering in the production of electrically refined steel which have a far greater influence on the cost of production than is generally credited. The most important of these is experience. It should be understood clearly that the electric furnace is a more delicate apparatus than any of the usual furnaces employed. It is more difficult to handle and its operation offers more likelihood of mishaps. Electric furnace operation has not yet been reduced to standard practice. Melters familiar with its operation are scarce and difficult to find."

Speaking about low power consumption, Mr. Clark has this to say:

"As a matter of fact, claims for low power consumption by any furnace should be received skeptically. It is a fact that the power consumption of any electric furnace depends somewhat upon the efficiency of the furnace, but it also depends to a far greater extent upon the thoroughness of the heat insulation, for, after all, the only heat which is lost is that which escapes by radiation or conduction. That which goes out in the slag, or in the steel, depends not upon the efficiency of the furnace, but upon its mode of operation. Where a high degree of refining is necessary, slags must be taken off at the cost of power consumption. Where the furnace must be operated with considerable time between the heats, heat is escaping rapidly during that idle time.

"Where heats must be held in the furnace, or melted slowly, to meet a definite schedule, a high power consumption must be expected. For these reasons it appears that the claims for low power consumption of certain furnaces are practically valueless from an operating standpoint. The conditions of operation, rather than the type of furnace, are what control the power consumption, though, of course, the construction of the furnace, as regards heat insulation, does have some influence."

Ease of Operation

As far as operation of electric furnaces is concerned, it is the general belief that considerable care and knowledge are required, and to cover this point to some extent we can continue to cite Mr. Clark's paper:

"To attempt an answer as to what type of furnace is best is as unsatisfactory as to make general comparison between electric furnaces and other furnaces. If we could accept at face value the statements of a number of men interested in the development of certain electric furnaces, we could easily believe that as soon as a foundryman has installed an electric furnace (provided he installed the right one) his troubles would be at an end. As a matter of fact, he is apt to find that they are just beginning. In the first place, unless the design of the furnace has been thoroughly tried out in practice, it will certainly have to be modified considerably from the designer's ideas. In the second place, the user will certainly find the furnace to be a more delicate piece of apparatus than he had anticipated. He will find that while he can make steel of a very high quality, he can also make, without difficulty, much steel of a very low quality. If there are in the society some men who have been using electric furnaces for the production of castings or special steels, they will have no difficulty in recognizing these remarks from one who has had such experience.

"It so happens that the speaker's experience has embraced not only a study in this country and Europe of the design and operation of a number of different types of furnaces, but has embraced the actual operation of two typical types of furnaces for the production of steel castings. The investigation as to which general type of furnace is best led in my case, as in that of most others, to much confusion of ideas. It is so evident that each type has certain advantages and disadvantages, and so impossible accurately to gauge the proper importance of the various advantages and disadvantages, that one cannot reach a conclusion as to which type of furnace is best wih confidence in his conclusion. Perhaps the only way to learn is to try them all. As a matter of fact, the speaker has already tried two, and feels that he has not yet decided the question."

Refining Possibilities

It is granted that as a refining medium the electric furnace cannot be excelled, but whether such extensive refining as indicated by Mr. Rennerfelt is commercial is very doubtful, for such reasons as were already expressed above (number of slags, meeting definite pouring schedules, etc.).

At the April meeting of the Electrochemical Society Mr. C. A. Hansen pointed out that:

"Current opinion has it that one of the advantages of the electric furnace is that it can work up any sort of charge. While this may be true quite often, it is not well to base estimates of the cost of molten electric furnace steel upon the usual published furnacing costs, and upon the local prices for stove scrap and similar materials. Probably every operator of an electric furnace has at one time or another run off heats from charges composed of stove scrap or its equivalent, and little need be said for or against such a procedure."

On the other hand, we all know that in the electrical industry, for considerations of permeability, steel must be of as low carbon content as can possibly be obtained. In the Tropenas Converter such low carbon can be attained at *no additional cost*, and almost pure iron can be cast inasmuch as at the end of the usual converter operation the steel contains only 0.09 per cent carbon, 0.02 per cent silicon and traces of manganese. To cast such metal high temperatures are required and the converter process presents the only means of obtaining such results commercially. Mr. C. A. Hansen says on the subject:

"With the electric furnace maintenance costs increase rapidly as the carbon contents of the product is brought down, and quite contrary to current opinion, it is not economical to turn out 0.10 carbon steel castings, although it is perfectly possible to do so."

Other authorities agree as to the difficulties encountered in the electric furnace when producing low carbon steels.

Loss from Oxidation

It is true that converter loss runs usually about 7 per cent higher than that of the electric furnace, but the conclusions drawn by Mr. Rennerfelt are quite erroneous. The fact that there is a higher loss in the converter does not affect the chemical analysis of the metal. At the end of the blowing operation silicon, manganese and carbon are practically burned out so that there can be no undesirable uncertainty of analyses, inasmuch as the very elements characterizing the steel are almost absent.

This is even one of the great points of superiority of the Tropenas converter over the electric furnace. When blowing is stopped, the analysis of the bath in the converter is almost constant so that *any* composition of steel can be obtained by the additions of the proper elements.

The converter practice which has been referred to by Mr. Rennerfelt must have been very poor, inasmuch as in this country we consider 18 per cent the maximum (instead of 28 and 33 per cent) which includes both cupola and converter losses. As far as temperature of metal is concerned, we believe that if higher ranges were attained in the electric furnace than are obtained in this country under ordinary practice in Tropenas converters, the life and stability of electric furnaces would be considerably endangered.

The best proof to the effect that converter metal does not cause scrap on account of low temperature is that all converter foundries in this country cannot make enough scrap and have to buy from 15 to 20 per cent of their actual cupola charges. As a matter of fact, one of the hardest things to find in an American converter foundry is home-made scrap.

In American practice we operate converters with lower silicon and higher manganese contents in the charge without injury to our linings. This is probably due to the elimination of brick and the substitution of ganister for linings after considerable study and experimenting.

Supply of Raw Material

Most of the electric furnaces operating in this country are run on an all-scrap basis in order to eliminate delicate and costly refining. All-scrap melting is, in our opinion, the only commercial course open to the electric furnace for the reason that the very smallness of most steel foundries does not allow the hiring of expensive melters. If this line of least resistance is followed, the electric furnace will encounter conditions similar to those of the old crucible furnace days. The law of supply and demand enters here into consideration, and it is useless to discuss the point, because as long as a market is created for steel scrap, the prices are bound to rise, and as the general opinion prevails that for the purpose of producing steel castings the electric furnace will be used as a scrap melter pure and simple, such market was created by the introduction of the electric process.

Reliability

In the light of the fifty analyses of consecutive blows published in our previous article and considering also the fact that this record is only a part of a series of over 22,000 similar operations, it is hard to conceive how the Converter process could be called a "hit or miss" method. This same point was raised when the Tropenas converter was brought out, and we always

refer with pleasure to the tests which the British Admiralty conducted in order to determine whether the open hearth process was more uniform and more reliable than the Tropenas converter.

The result of these tests cannot be published, but the fact that several Tropenas converters were installed after the tests were completed speaks louder than words.

To the practical foundryman it is perfectly clear that wherever the personal equation does not enter into consideration, greater regularity and consequently greater reliability can be expected. As stated in our previous article, converter operation hinges around good cupola practice. There is no simpler furnace to operate than a cupola, the practice has been reduced to definite standards, so that the operation of the Tropenas converter itself is purely mechanical. The best proof of this statement is found in the very lack of understanding on the part of the average converter operator, of the actual reactions taking place during the blowing.

Suitability of Process to Product

Mr. Rennerfelt cites an article published in *The Iron Age* of March 27, 1913, by Mr. E. F. Lake, in which Tropenas converter steel castings are not treated in a very complimentary way. We were tempted, at the time the above-mentioned article appeared, to take up the cudgel for the converter castings, but the statements made were so evidently the product of great enthusiasm for a new method that we disregarded their being at variance with actual facts.

To anyone who has followed the development of the steel castings industry in this country it is known that the Tropenas converter has steadily displaced the crucible process, and we venture to say that the days are not far off when the number of crucible steel foundries manufacturing steel castings will be counted on the fingers of one hand.

The lack of control over carbon contents gave the crucible process its death blow, and the only surprise which can be evinced is that the other inconveniences inherent to this process had not forced its users to a change long ago.

Former crucible furnace men, who are today strong Tropenas converter enthusiasts, tell us that their product is today so superior to that they used to turn out that they are able to satisfy clients which the crucible had lost to them.

It will be of interest to note that in the automobile industry, where the utmost care has been exercised in the drawing up of rigid specifications, over 95 per cent of the steel castings used are the product of the Tropenas converter. It will also be of further interest to note that at least two large motor truck manufacturers who had found it to their advantage to purchase steel castings from one of the best electric furnace steel producers in Europe are now using castings made in the Tropenas converter exclusively.

We do not want the reader to infer from the above that steel castings produced in the electric furnace are not of the highest grade, because under good management the electric furnace will produce a superior casting, but under ordinary conditions the electric steel casting will suffer the disease of all things that are superior, namely, it will be too expensive for the quality achieved.

This leads us to remember the remark of one of our Boston friends who, when called upon to purchase an electric furnace instead of a Tropenas converter said, "Why buy silk stockings when cotton ones will do?"

Flexibility of Process

We are afraid that Mr. Rennerfelt's suggestion to use mixers in connection wih the electric furnace in order to increase the latter's range, is not very practical. The primary superheating of the steel or the suggested use of thermit would only add to the cost of a product which is already in great danger of being too expensive, and our suggestion would be to use the electric furnace within the range of its own capacity and make the best of a process which has no flexibility.

The pouring of castings weighing 3 or 4 times the rated capacity of any Tropenas converter is the simple result of speedy operation which is not and will never be met by any electric furnace.

It might be said in passing that contrary to the usual belief, Tropenas converters are not lined with bricks but with ganister, which accounts for the ease with which 3 operations can be made in an hour, 20 and even 25 in an ordinary working day, and from 36 to 40 without need of repairs.

Segregation of Steel Castings

If the leading authorities were to be consulted today regarding the order in which the various metalloids will segregate in steel, a goodly number of volumes would be filled with dissenting opinions. The writer's contention was based on the opinion that the electric furnace can be used commercially only as a steel-scrap melting device, and in such a case the final product will always be higher in carbon than the scrap used, because the analysis of the average steel scrap shows carbon contents which are too low for steel castings purposes.

The resulting "home scrap" made of gates and risers will produce a "building up" of carbon similar to that which is claimed to occur for phosphorus, sulphur and copper in the converter process.

If, according to certain authorities, carbon being present in larger quantities in steel than any other metalloid, segregates first then segregation will be greater in the electric process; if sulphur and phosphorus segregate first, the segregation will be greater in converter steel.

The above, however, is important only in the manufacture of ingots. In the production of steel castings such interest is not surprising when originating from the Tropenas converter, the bodies of metals are so small that segregation need not be considered.

Market for Various Steel Castings

We must thank Mr. Rennerfelt for the tribute paid by him to the various manufacturers interested in the production of better steel castings. The fact that inquiries are being made about electric furnaces proves without a doubt that interest has been aroused, but such interest is not surprising when originating from a country where it is almost a cult to produce "the best in the world."

One fact, however, must not be lost sight of, namely, that it is one thing to manufacture a product and still another to sell it.

American manufacturers are open to conviction. They are using old and tried methods for producing steel castings and we are sure that any medium of increasing quality will be received with favor. Its general use, however, will remain problematical as long as increased cost of production is not commensurate with betterment of quality.

Tropenas Converter Co.,
New York City.

The Nevada State Mining Laboratory, now organized as a department of the Mackay School of Mines, has for its object the free analysis of ores, rocks and minerals taken from within the boundaries of Nevada by citizens of the state. In 1914 assays were made for 804 persons who sent in 1631 samples from 248 localities. A total of 6533 determinations were made on these samples.

Presentation of the Perkin Medal to Edward Weston

The ninth impression of the Perkin Medal was presented to Dr. Edward Weston, president of the Weston Electrical Instrument Company of Newark, N. J., on the evening of January 22, 1915, in a joint meeting of the New York sections of the Society of Chemical Industry, the American Chemical Society, and the American Electrochemical Society. The medal had been awarded to Dr. Weston unanimously at the meeting last month of the Perkin Medal Committee, consisting of representatives of the above three and other allied chemical societies.

The meeting of January 22 was very well attended, many ladies being present, and lasted till almost midnight. It was called to order by the chairman of the New York Section of the Society of Chemical Industry, Dr. G. W. THOMPSON. The Perkin medal was presented to Dr. Weston by Dr. Charles F. Chandler, Senior Past President of the Society of Chemical Industry in America.

Yours Sincerely
Edward Weston

DR. CHANDLER'S PRESENTATION SPEECH

Dr. CHARLES F. CHANDLER, in his presentation address, spoke of the early life of Weston. Edward Weston was born on May 9, 1850, at Bryan, near Oswestry, Shropshire, England. While he was still young his father moved to Wolverhampton in Staffordshire, where he was educated under private tutors, receiving his first instruction in physics and chemistry.

By this time even he had already manifested a great taste for science and also for experimenting and occupying himself in the use of mechanical tools. His parents desired him to select some well established profession for his life work, and they first placed him with a dentist, but this did not suit his tastes. Then they tried him with two physicians, Dr. K. H. and J. E. Colman. He decided that he could stand surgery, but he did not like medicine. But these physicians exercised a most beneficial influence upon him because they were broad-minded scientific men, both of them in the habit of lecturing on scientific subjects and illustrating them by experiments. So Weston's interest in chemical, metallurgical and electrical subjects, which he had developed while he was still a boy, was greatly increased by his association with these men.

While still only sixteen years of age he delivered an illustrated lecture on electricity, performing the experiments with apparatus which he had himself constructed. The fact soon become apparent to him that he had no taste for the practice of medicine, so he determined to leave home and strike out for himself. Armed with some letters of introduction, he prepared to go to London, but on thinking the matter over he finally concluded to go to America and make a career there, which he certainly has done. He arrived in New York in May, 1870, with his modest library and outfit of chemical and physical apparatus, and a very limited amount of cash and a very simple wardrobe.

He began at once to look for employment, tramping daily through New York, Long Island and everywhere where he thought chemical operations were carried on. Finally he ran across the small concern of William H. Mardock & Co., manufacturers of photographic chemicals and dealers in photographic supplies and apparatus. Here he made his beginning, manufacturing pyroxyline and a general line of photographic chemicals, staying about a year. During this period and later, for about three years, he assisted Professor Charles S. Stone, Professor of Chemistry, at the Cooper Union.

He watched the daily papers and one day saw an advertisement for a man having some chemical and electrical knowledge, especially electroplating. He answered this advertisement and the next morning a man came to the store and inquired for Weston. This man was a representative of William H. Belden, president of the American Nickel Plating Company. After a short interview Mr. Belden proposed to engage him at once, but he felt that he could not leave his employers so suddenly, and arranged to continue his position with Mardock & Co. for a fortnight and to work nights in Belden's establishment. He found that the nickel-plating works were in very poor shape, especially the galvanic batteries employed as a source of electricity. He went to work immediately, put the batteries and other things in order and at the end of two weeks everything was working satisfactorily.

When Dr. Weston took his position with the American Nickel Plating Company he made most careful investigation into all the details of the art, and made many improvements in these details, by which he improved the quality of the coating, secured great economy in nickel, and greatly reduced the time required for plating, and particularly succeeded in the preparation of the surface to which the nickel was to be applied and in the polishing of the nickel coating. He also discovered a dip which could be conveniently used for removing nickel from damaged goods in order to coat them again. With these improvements the business of the company increased very rapidly and they nickel-plated the greatest variety of articles from a bunch of keys to a fire engine.

Owing to dissensions among the stockholders of the company, the business was finally given up. Weston then went to the Silver Nickel Plating Company about the middle of 1872. He found the process they were carrying on was entirely unsatisfactory and turned the place into a nickel-plating business. He soon left the company, however, and was appointed consulting expert by the Commercial Printing Telegraph Company, operating the patents of Foot and Randall. The company was soon bought out by the Gold and Stock Telegraph Company.

Dr. Weston then formed a partnership with a Mr. Harris under the firm name of Harris & Weston for general plating business; copper, brass, nickel, silver and gold. Here he built, in the latter part of 1872, a dynamo as a substitute for batteries in electroplating. This greatly increased his business, so he enlarged the plant and finally moved to Center Street. Here he built another dynamo, larger and somewhat different. Then he built a third dynamo for a manufacturing firm in Newark. At this time he withdrew from the plating business and made an arrangement with the Newark firm to build a dynamo for electroplating and made about twenty of them. They were so expensive, however, that they could only be used by large concerns. He started to design a simpler and cheaper machine, but the firm decided to give up the business. A new firm, Stevens, Robbins & Hayville, bought them out and Weston went into partnership in order to develop a new nickel anode which he had invented and for which he obtained his first patent in 1875.

Born in 1850, Weston was twenty years of age when he came to America in 1870, and he took out his first patent in 1875 at the age of twenty-five. The record of his varied

experience, his efforts and successes for the first five years of his working life is certainly very remarkable, and gave promise of all that he has accomplished since. He has taken out over 350 patents for his various inventions, and has made radical improvements in several arts. Besides that, a great deal of his work has involved the most patient and careful scientific investigations, often of microscopic accuracy, and has contributed largely to the advance of scientific knowledge and theory.

It would give me a great deal of pleasure to explain to you in detail the great variety of subjects which Dr. Weston has investigated and developed during the forty years since he took out his first patent, but as I am to be followed by Dr. Baekeland, Dr. Hering and by Dr. Weston himself, I must deny myself the pleasure.

In 1903 McGill University conferred upon Mr. Weston the degree of LL.D., in 1904 the Stevens Institute of Technology bestowed the degree of D. Sc., and in June, 1910, Princeton University conferred the same degree.

Edward Weston, Doctor of Laws and Doctor of Science, my dear friend: It gives me the greatest pleasure as the representative of the affiliated chemical and electro-chemical societies to place in your hands this beautiful token of appreciation and affection of your fellow chemists.

Dr. Weston, after receiving the Perkin medal, expressed his thanks in a felicitous little speech, in which he gave reminiscences of his first meeting with Dr. Chandler many years ago.

Dr. Baekeland's Speech

Dr. Leo H. Baekeland in his address on "Edward Weston's Inventions" said that Edward Weston's pioneer work was not easy to describe in a few words, as his restless inventive activity has been spread over so many subjects, has intertwined so many interlocking problems—electrodeposition of metals, electrolytic copper refining, construction of electric generators and motors, illumination by arc and incandescent lamps, and the manufacture of electrical measuring instruments. An impressive list of subjects, but in every one of those branches of industry, Weston was a leader.

But why was Weston able to overcome difficulties which seemed almost unsurmountable to his predecessors and coworkers in the art?

The answer is simple: He introduced in most of his physical problems a chemical point of view—a chemical point of view of his own; a point of view which was not satisfied with general statements, but which went to the bottom of things. He did not get his chemistry wholesale as it is dispensed in some of our hot-bed-method educational institutions. He had to get at his facts piece-meal, one by one, adjust them, ponder over them, collect his facts with much effort and discrimination; he did not acquire his knowledge merely to pass examinations, but to use it for accumulating further knowledge.

It seems rather fortunate for him that one of the first employments he got in New York was with a chemical concern which made photographic chemicals. This was the time of the wet-plate, when photographers made their own collodion, their own silver bath, their own paper. Whoever went through those delicate operations, knew the difficulties, the uncertainties which were caused by small variations in the composition of chemicals or in the way of using them. Photochemistry is excellent experience for any young chemist who is disposed to generalize too much all chemical reactions by mere chemical equations. Whoever has to deal with those delicate chemical phenomena, which occur in the photographic image, knows that many unforeseen facts can not easily be accounted for by our self-satisfying but often superficial generalizations of the text-books.

Weston's tendency to observe small details in chemical or physical phenomena led him to improve the art of nickel-plating and electrolytic deposition of metals to a point where it entered a new era. When he undertook the study of the difficulties in this art, he took nothing for granted, but by close observation, he succeeded in devising methods not only of increasing the physical texture of the deposit, but for improving enormously the speed and regularity with which the operations could be carried out; all these improvements are now embodied in the art of electrotyping, nickel-, gold-, and silver-plating.

At this time, attempts had already been made for the commercial refining of copper by means of the electric current. But this subject was then in its first clumsy period, far removed from the importance it has attained now among modern American industries. Here again, Weston brought order and method, where chaos reigned. His careful laboratory observations, harnessed by his keen reasoning intellect, established the true principles on which economic, industrial, electrolytic-copper-refining could be carried out. Dr. James Douglas (Commencement Address, Colorado School of Mines, *Metallurgical and Chemical Engineering*, Vol. XI, No. 7, July, 1913, page 377) referred to this fact in a recent address:

"I suppose I may claim the merit of making in this country the first electrolytic copper by the ton, but the merit is really due him (Weston) who in this and innumerable other instances, has concealed his interested work for his favorite science and pursuits under a thick veil of modesty and generosity."

The whole problem of electrolytic refining, when Weston took it up, was hampered by many wrong conceptions. One of them was that a given horsepower could only deposit a maximum weight of copper, regardless of cathode- or anode-surface. This fallacious opinion was considered almost an axiom until Weston showed clearly the way of increasing the amount of copper deposited per electrical horsepower, by increasing the number and size of vats and their electrodes, connecting his vats in a combination of series and multiple. The only limit to this arrangement being the added interest of capital and depreciation on the increased cost of more vats and anodes, in relation to the cost of horsepower for driving the dynamos.

The electrodeposition of metals forced Weston into the study of the construction of dynamos. Until then, the electric current used for nickel-, silver- and gold-plating, as well as for electrotyping, was obtained from chemical batteries. Weston says that it was almost a hopeless task to wean electroplaters from these cells to which they had become tied by long experience and on the more or less skilful use of which they based many of the secrets of their trade.

If the dynamo as a cheap and reliable source of electric current was advantageous for nickel-plating, it became an absolutely indispensable factor for electrolytic copper refining. At that time, the dynamo was still at its very beginning, some sort of an electrical curiosity. It had been invented many years before by a Norwegian, Soren Hyjorth, who filed his first British patent as far back as 1855. Similar machines had been built both in Europe and America, but little or no improvement was made until Weston, in his own thorough way, undertook the careful study of the various factors relating to dynamo efficiency.

Dr. Baekeland then sketched Weston's work in dynamo design, for which he worked out the first patent in 1876, and mentioned that the first practical application of electric power transmission for factory purposes in this country was in the Weston factory in Newark.

Weston's work in illumination was sketched next. Weston started the manufacture of arc-lamp carbons in this company which he continued until 1884. To improve the color he invented what is now called the flaming arc.

In relation to this invention, it is interesting to quote the following extract of the specifications from his United States Patent 210,380, filed November 4, 1878: "This rod or stick may be made of various materials—as, for example, of so-called lime glass, or of compounds of infusible earths and metallic salts, silicates, double silicates, mixtures of silicates with other salts of metals, fluorides, double fluorides, mixtures of the double fluorides, fusible oxides, or combinations of the fusible oxides with the silicates—the requirements, so far as the material is concerned, being that it shall be capable of volatilization when placed on the outer side of the electrode to which it is attached, and that its vapor shall be of greater conductivity than the vapor or particles or carbon disengaged from the carbon electrodes. The foreign material added to the carbon may be incorporated into the electrode by being mixed with the carbon of which the electrode is composed, or it may be introduced into a tubular carbon; but I have found it best to place it in a groove formed longitudinally in the side of the electrode, as shown."

In his endeavors to make the electric incandescent lamp an economic possibility, we see him introduce over and over again, chemical methods and chemical considerations. He first tried to utilize platinum and iridium, and their alloys, which he fused in a specially constructed electric furnace, devised by him, antedating the furnace described by Siemens. This is probably the first electrical furnace, if you will except the furnace which Hare used in his laboratory in Philadelphia.

But these platinum metals showed serious defects aside from their high cost, and by that time, Weston had become so familiar with the properties of good carbon that like

other inventors, he became convinced that the ultimate success lay in that direction.

Dr. Baekeland then sketched Weston's work on incandescent lamps. The fatal defect of early lamps was structural lack of homogeneity. There would be points with a high resistance and these would burn out.

Weston tried to solve this difficulty by means of his chemical knowledge. He remembered that as a boy, when he went to visit the gas works to obtain some hard carbon for his Bunsen cell, this carbon was collected from those parts of the gas retort which had been the hottest, and where the hydrocarbon gas had undergone dissociation leaving a dense deposit of coherent carbon.

In this chemical phenomenon of dissociation at high temperature, he perceived a chemical means for "self-curing" any weak spots in the filament of his lamp. The remedy was as ingenious as simple. In preparing his filament, he passed the current through it while the filament was placed in an atmosphere of hydrocarbon gas, so that in every spot where the temperature rose highest on account of greater resistance, brought about by the irregular structure of the material, the hydrocarbon gas was dissociated and carbon was deposited automatically until the defect was cured, with the result that the filament acquired the same electric resistance over its whole length.

But this invention, however, brilliant, did not limit his efforts. He had become imbued with the idea that the ideal filament would be an absolutely structureless, homogeneous filament, with exactly the same composition and the same sections throughout its whole length. He reasoned that such a filament could not be obtained from any natural products, neither from paper nor bamboo, but that it had to be produced artificially in the laboratory from an absolutely uniform, structureless chemical substance. After various unsuccessful attempts, he finally secured this result by applying his old knowledge of the days when he used to make collodion. He produced a homogeneous, structureless transparent film of nitrocellulose by evaporating a solution of this material in suitable solvents. As he could not carbonize this film on account of the well-known explosive properties of so-called "gun-cotton," he obviated this difficulty by eliminating the nitrate group of the molecule of cellulose-nitrate by means of ammonium-sulphydrate. This gave him a flexible, transparent sheet, very similar in appearance to gelatine; this material he called "tamidine." Such films could be cut automatically with utmost exactitude, producing filaments of uniform section, which then could be submitted to carbonization, before fastening them to the inside of the glass bulb of the incandescent lamp.

It is interesting to note here that the modern tungsten lamp, in all its perfection, made of ductile tungsten, is after all, the fullest development of the principle of an entirely structureless, homogeneous chemical filament. The tungsten-filament can stand much higher temperatures than carbon and this property gives it higher lighting efficiency, but the former tungsten filaments of a few years ago, which had a granular structure, had the same defect as the earlier carbon lamps, namely, a non-homogeneous texture and correspondent short life.

While Weston was wrestling with all his electrical problems, and more particularly with the construction of dynamos and motors, he was handicapped continuously by the clumsy and time-consuming methods of electrical measurements which were the best existing at that period. Up till then, these methods had been found good enough for physical laboratories, where the lack of accuracy did not result disastrously in hitting the pocket of the manufacturer, or where time—abundant time—for observations and calculations was always available. But progress in the electrical industries lagged behind the delay and uncertainties caused by electrical measurements.

So Weston was compelled to invent for his own use a set of practical electrical measuring instruments. It was not long before some of his friends wanted very badly duplicates of his instruments; before he knew it he was giving considerable attention to the construction and further development of these instruments.

Just about this time the electric light and dynamo construction enterprise entered into a new period where they began to develop in large unwieldly commercial organizations, requiring public franchises and which had to be backed by vast amounts of new capital. In its boards of directors business men or financial men and corporation lawyers became paramount factors and eclipsed in importance the technical or scientific men, who, in earlier days, had almost exclusively contributed to the development of the art.

Following his natural inclinations, Weston soon abandoned his former business connections in order to entrench himself in a field where individuality, science and technology were of almost unique importance, and which he could develop without the necessity of incurring financial obligations beyond what he could master personally. Thus he dropped his connections with the electric light and dynamo enterprises and we see him now, heart and soul, in another new industry which he created—the art of making accurate, trustworthy and easy-to-use electrical measuring instruments. Did he foresee at that time that this art would attain the magnitude to which he has brought it to-day? Did he dream that his early modest shop was to develop into one of the most remarkably equipped factories in the world; an institution which seems the embodiment of what industrial enterprises may look like in future days, when scientific and liberal minded management will have become the rule instead of the exception.

In his factory in Newark, Weston seems to have instilled some of his own reliability and accuracy in the minds of the men and women he employs.

In fact, has it occurred to you that even a man with the widest knowledge and the highest intelligence, who is not scrupulously reliable and careful, who is not the soul of honesty personified, could not make honest and trustworthy measuring instruments nor create reliable measuring methods?

What Stas did in chemistry for atomic weights, Weston did for electrical measuring; he created radically new methods of measurement and introduced an accuracy undreamt of heretofore. Do not forget that his problems were not easy ones. When the British government offered a prize of $100,000 for the nearest perfect chronometer, the problem of a reliable chronometer involved considerably less difficulties and fewer disturbing factors than those encountered in devising and making electrical measuring instruments. But here again, even at the risk of monotonous repeating, I want to impress you with the fact that the success of the methods of Weston was found in almost every case in the application of chemical means by which he tried to solve his difficulties.

When he took up this subject, the scientists, as far back as 1884, accepted implicitly the belief that the definition of a metal and a non-metal resides in a physical distinction; that for metals the electrical resistance increased with temperature, while for non-metals, their resistance decreased with temperature. This was another one of those readily accepted axioms which nobody dared to refute or contest because they were repeated in respectable text-books.

And yet this unfortunate behavior of metals was the greatest drawback in the construction of accurate measuring instruments. Indeed, on account of the so-called temperature coefficient, all measurements had to be corrected by calculation to the temperature at which the observation was made. This seems easy enough, but it was time-consuming and often it is more difficult to make rapid accurate observation of the temperature of the instrument itself. First of all, the thermometers are not accurate, and have to be corrected periodically, and furthermore, it is not an easy matter to determine rapidly the temperature of a coil or instrument. Moreover, by the very passage of the electric current, fluctuating changes in temperature are liable to occur, which would make the observations totally incorrect. All this led to hesitation and slowness in measurements.

Weston wanted to correct this defect, but he was told that the very laws of physics were against his attempts. Before he was through with his work, he had to correct some of our conceptions of the laws of physics; now let us see how he did it:

Weston knew that the favorite metal for resistances was so-called German silver. Strange to say, he was the first one to point out to the Germans themselves that "German silver" is a word which covers a multitude of sins, and that the composition of German silver varies considerably according to its source of supply. The result was that he soon proposed a standard copper- and nickel- and zinc-alloy containing about 30 per cent. of nickel, and which had a resistance of almost twice that of ordinary German silver and a much lower temperature co-efficient.

Not satisfied with this, he took up the systematic study of a large number of alloys. The first batch which he undertook to study amounted to more than 300 different alloys. Since that time, he has considerably increased this number, and is still busy at it. Everyone of these alloys he made himself in his laboratory, starting from pure materials, and controlling the whole operation from the making of the alloy to the drawing of wires of determined size. By long and repeated observations, on which many years have been consumed, he was able to determine the electrical behavior of each one of these alloys at different temperatures.

After awhile, he began to observe remarkable properties

in some manganese alloys he compounded. He managed to produce an alloy which had sixty-five times the resistance of copper. But getting bolder and bolder, he strove to obtain an alloy which had no temperature-coefficient whatever. He not only succeeded in doing this, but finally, produced several alloys which had a *negative* temperature-coefficient. In other terms, their resistance, instead of increasing with rise of temperature, decreased with increasing temperature. He also showed that the resistance of these alloys depended not only on their composition, but on certain treatments which they undergo, for instance, preliminary heating. And since that day, the physicists have had to bury their favorite definition of metals and non-metals. The present generation can hardly realize what this discovery meant at that time. I could not better illustrate this than by reminding you of the fact that in 1892, at the meeting of the British Association for the Advancement of Science, where it was urged to found an institution similar to the Deutsche Reichsanstalt, Lord Kelvin said in his speech:

"The grand success of the Physikalische Reichsanstalt may be judged to some extent here by the record put before us by Prof. von Helmholtz. Such a proved success may be followed by a country like England with very great profit indeed. One thing Prof. von Helmholtz did not mention was the discovery by the Anstalt of a metal whose temperature co-efficient with respect to electrical resistance is practically nil; that is to say a metal whose electrical resistance does not change with temperature. This is just the thing we have been waiting for for twenty or thirty years. It is of the greatest importance in scientific experiments, and also in connection with the measuring instruments of practical electric lighting, to have a metal whose electrical resistance does not vary with temperature; and after what has been done, what is now wanted is to find a metal of good quality and substance whose resistance shall diminish as temperature is increased. We want something to produce the opposite effect to that with which we are familiar. The resistance of carbon diminishes as temperature increases; but its behavior is not very constant. Until within the last year or so nothing different was known of metals from the fact that elevation of temperature had the effect of increasing resistance. The Physikalische Anstalt had not been in existence two years before this valuable metal was discovered."

Then followed this colloquy:

"Prof. von Helmholtz—The discovery of a metal whose resistance diminished with temperature was made by an American Engineer.

Prof. Ayrton—By an Englishman—Weston.

Lord Kelvin—That serves but to intensify the position I wished to take, whether the discovery was made by an Anglo-American, an American Englishman, or an Englishman in America. It is not gratifying to national pride to know that these discoveries were not made in this country."

The misinformation of Kelvin was due to the fact that after the Weston patents had been published, his alloy was called *manganin* in Germany, and quite some publicity had been given to its properties with scant reference to its real inventor, an occurrence which, unfortunately, is not unfrequent not only among commercial interests but in technical or scientific circles as well.

No less important was the invention of the Weston cell, which in 1908, by the international commission for the establishment of standards of electrical measurements, has become the accepted universal practical standard for electromotive force. Here again, this physical standard was obtained by chemical means. . . .

"Dr. Weston assures me that he has succeeded in making his alloys to show only a change of one-millionth for a variation of 1 deg. C. The metallic alloys he discovered are used practically in nearly all kinds of electrical measuring instruments throughout the world. Weston instruments and Weston methods are now found in all properly equipped laboratories and electrochemical establishments of the world. On a recent trip to Japan, I saw them in the University of Tokio, as well as in the Japanese war museum, where their battered remains attested that the Russians used them on their captured battleships. I have worked in several laboratories in Europe equipped with an instrument said to be "just as good" as those of Weston, but in most instances they were imitations of Weston instruments and it was significant that they kept at least one Weston instrument to be used to correct and compare their national product.

"Like many inventors, Weston has been engaged extensively in patent litigation. To uphold some of his rights, he had to spend on one set of patents nearly $400,000, a large amount of money for anybody, but as he told me, he begrudges less the money it cost him than all his valuable time it required—a greater loss to an inventor thus distracted from his work. What is worse, most of this litigation was so long-winded that when finally he established his rights, his patents had aged so much that they had lost, in the meantime most, if not all, of their seventeen years' term of limited existence. And here I want to point out something very significant. In the early periods of his work, between 1873 and 1886, Weston took out over 300 patents. Since then, he has taken considerably less, and of late, he has taken out very few patents, after he became wiser to the tricks of patent infringers.

"Formerly, as soon as he published his discoveries or his inventions, in his patent specifications, he was so much troubled with patent pirates that instead of being able to attend to the development of his inventions, he was occupied in patent litigation. As an act of self-preservation, he has had to adopt new tactics. He now keeps his work secret as long as possible, and in the meantime spends his money for tools and equipment for manufacturing his inventions. In some instances, this preparation takes several years. Then by the time he sends any new type of instruments into the world, and others start copying, he has already in preparation so many further improvements that pretty soon the next instrument comes out which supersedes the prior edition.

"He had to utilize these tactics since he found how impractical it was to rely on his patent rights for protection. That inventors should have to proceed in this way is certainly not a recommendation for our patent system; it kills the very purpose for which our patent laws were created, namely, *the prompt publication of new and useful inventions.*

Dr. Weston's Address

Dr. Edward Weston made a very interesting and thoroughly characteristic address. As he had a cold, he started with a low and hoarse voice, but it grew stronger as he kept on, and he stuck to his subject until he had brought out what he wanted to say. He had no prepared speech, but spoke off-hand. He told delightful reminiscences of his doings with men and customers, how they had to be handled and educated, how early troubles were changed into final successes, and how endless research work had to be kept up to achieve results. This informal way of talking made his speech particularly charming in its personal directness to his audience. But it also deprives us of the privilege of publishing the address now in full. We cannot do better than give a rough outline of his speech at this time.

Dr. Weston said he was glad he had acquired from his work in chemistry that exactness and experience which can only be obtained from chemistry. He had always been together with chemists. He regretted that the specimens of his early chemical and physical work had been packed away in boxes and were therefore not available now.

Dr. Weston first dealt at considerable length with his early work on nickel plating. The public had to be educated and the platers had to learn how to do it. In general there was no difficulty with the solutions themselves. The trouble was mainly in the use of methods that were employed in the deposition of silver, thus overlooking the fact that silver is soft and nickel is hard. Dr. Weston explained in detail what this difference meant and dealt especially with the methods of cleaning and the substitution of chemical for mechanical cleaning.

During this work Weston got impressed with the fact that nickel is hard, and asked himself whether it would be possible to get softer nickel. He found indeed a method of depositing "malleable nickel" that can be rolled. In this connection Dr. Weston discussed at length the problem of single salts versus double salts.

Dr. Weston recited various cases of troubles, especially the fact that when a single salt is used, first a good deposit is obtained, but after a time it loses its white color, gets darker and assumes a green tint and hydrogen is evolved. This is due to the fact that the solution becomes more and more basic. As soon as acid is added, the deposit becomes all right again.

Weston's work on nickel finally led him to the invention of a new nickel anode and a new nickel solution.

From nickel plating Dr. Weston turned in his address to dynamo design. His first dynamos were built for the plating business and again the platers had to be educated. Dr. Weston told amusing instances of what this meant. Of course, the high first cost was the objection. Weston changed and improved the designs many times,

one of his principal objects being to build cheaper machines.

Dr. Weston then discussed his work on the arc lamp. The cost of imported arc lamp carbons was then $1.20 a dozen when delivered here; that was the reason why he started the manufacture of carbons. In his further work he wanted to change the color, but also wanted to get more light per horsepower. Further he wanted to steady the arc. This led him to the invention of the flaming arc.

When he turned to incandescent lamps, the "subdivision of light" was under considerable discussion. With arc lamps the problem was mechanical, one of regulation. With incandescent lamps a very complicated chemical and mechanical problem was to be solved, and the chemical problem was very severe.

The total resistance of the lamp filament must have a uniform value in all lamps. But this is not enough, since it is necessary that the resistance be uniform all along the length of the filament. In the early filaments, for instance, those made from paper, this was not the case, the fibres being arranged crosswise in all directions. The filament would have high-resistance spots which would burn through. Weston solved this problem by heating the filaments electrically in hydrocarbon vapor whereby a deposit of carbon would form faster on hot spots than elsewhere. This method solved two problems. One was to get the resistance uniform all along the length. The second was that by carrying this operation on long enough it was possible to give to the filament exactly the desired total resistance.

At this point of the address the fighter in the man Weston showed himself in a very characteristic and interesting manner when he discussed the invention of this chemical control of resistance and the fact that the courts had ruled against him in this case.

But the fundamental problem of getting a perfectly uniform structureless filament was later solved by Dr. Weston in another way by extended chemical research. (See Dr. Baekeland's paper above.)

Dr. Weston then gave a review of his work on alloys, starting with German silver and then extending to many hundreds of different alloys. The chief object of this research was to get alloys with the desired resistivity and temperature coefficient for measuring instruments. Manganese is the chief resistance-giving element, nickel comes next. But chemical composition is not everything, since the temperature coefficient depends also on the heat treatment, whether the wire is hard-drawn or annealed. For each alloy it was, therefore, necessary to find the correct heat treatment. This was illustrated in an interesting way by curves exhibited in diagrams on the wall.

Dr. Weston finally spoke briefly of the invention of his standard cell and how he came to use cadmium sulphate.

Dr. Hering's Address

The final address on the program was by Dr. CARL HERING on "Some of Dr. Edward Weston's Achievements in the Field of Electricity."

It is not an exaggeration to say that the rapid development of the electrical industry is in no small part due to the direct-reading electrical measuring instruments which he contributed to the art, and which were of such a high order of accuracy, constancy, reliability, portability and simplicity of application, that it became not only possible but even quite easy to make really reliable measurements, whereby progress in the electrical industries was greatly facilitated. It may be said that the whole space of a room of a laboratory equipped with instruments, has now been reduced by him to a couple of coat pockets, in which the instruments for such measurements may now be carried.

Having myself been engaged in electrical work in that early and trying period when measuring instruments were so sorely needed, as so much of importance had to be discovered by measurements of currents and voltages, and when all but the crudest of these measurements were tedious, difficult, complicated and unreliable, and were generally limited to the use of the laboratory galvanometer, I can personally vouch for the statement that the advent of the Weston instruments marked a turning point in the development of the electrical industry.

More than that, it was a matter of even national interest, for prior to that time the "precision" instruments (in name though not in fact) were imported from abroad. Europe was ahead of America, but now Weston has turned the tables, Europe imports large quantities of these instruments from us. Some years ago, in a visit to the German Reichsanstalt where some of the best research work in the world was being done with the best instruments the world could produce, I noticed, with no little national pride, that Weston instruments, made in America, were in universal use there, and this, in that one of all the European countries which prided itself most for its development of the instrument art.

He early realized that in the successful manufacture of many of the articles used in the electric industry, especially when made on a large scale, such as incandescent lamps, it was essential that reliable and accurate electric measurements be made quickly and by inexperienced labor; he argued that such measurements should be as easy to make as those with the foot rule and the balance. Though considered utopian in those early days, he persisted and finally succeeded in accomplishing it; the accurate measuring of amperes and volts became as simple as reading the dial of a spring balance, and the accuracy and reliability greatly exceeded it. Indeed it may be justly said that he created the art of practical electrical measurements in the industries, with direct reading, portable instruments requiring no trained experience, to a degree of accuracy equal to and often exceeding that formerly obtained with far more complicated apparatus in laboratories, by skilled and experienced men.

One of the essential factors in making such rapidly repeated measurements in the manufacturing industries, was the avoidance of having to make the troublesome correction calculations, such as those due to changes of temperature. As existing metals and alloys were very inadequate in this regard, for resistance materials, on account of their temperature corrections, Dr. Weston, with the determination, persistence and indefatigability which are so characteristic of all his work, and with rare courage in attacking especially difficult problems, set himself the task of finding something better, and as usual he succeeded, giving to the world the alloy now known as manganine, a copper, manganese, nickel alloy, which combined the two very desirable features of a very small temperature coefficient and a high resistivity. The importance of this alloy is shown by the fact that it is now used and adopted internationally. Though the Germans for a time claimed priority in its discovery or invention, they seem now to give him the credit, even to the extent of suggesting calling it "Westonine."

Having succeeded in what he was determined to find or produce, Dr. Weston does not rest, as most men do; on the contrary, he at once starts to get something still better; he is his own strongest and most determined competitor. The world was glad to get manganine, but he wanted something more; he wanted an alloy of practically no temperature coefficient, and having then gotten this, he wanted still more, a negative coefficient, something which there was no reason to think existed. As usual, he succeeded in producing it, but still was not satisfied until he had found several of them. The vastness of this metallurgical research will appeal to one when it is considered that there are quite a number of available metals, and that the various possible combinations of these in groups of two, three, four and more in different proportions, is practically infinite.

Nor did it satisfy him to find an alloy that had this desired quality, as it would be useless if it could not be drawn into a wire. Many of these alloys were stubborn and various thermal and mechanical operations had to be found before these otherwise desirable alloys could be made to yield to the wire drawing process. The thermo-electric properties when in contact with other metals also were an important factor and added to the complications.

The best standard cell known in those early days, for serving as a concrete voltage standard, was not considered by him to be up to his standard of ideals, and indeed it was a troublesome apparatus to use; so he gave himself the task of producing a better one; one which was more easily reproducible and had a lower temperature coefficient; the fact that many others all over the world had tried it but were unsuccessful, rather encouraged than discouraged him. As in other problems which he undertook, he succeeded, and gave to the world something far better

than the best it had had, and the world recognized it by making it the international standard; even the Germans now call it the Weston standard cell, though for years they contested the priority of invention. Its predecessor, the Clark cell, is now fast finding its way to the shelves of the museums.

Not satisfied with this standard of reference in which the solution was saturated at all temperatures, he also produced a working cell, the so-called unsaturated one, which saves the user some correction calculations, as it has a still better temperature coefficient.

That his instruments were ranked by electrical engineers as of the highest standard is best shown by the fact that the highest claim that competitors could make was that their instruments were "as good as a Weston," whether true or not. It was the pride of laboratories to be equipped with Westons. Disputed measurements were settled by using Westons. When a particular measurement was difficult or troublesome to make, Weston was appealed to to make an instrument to do it easily. Even electrical capacities can now be measured with a portable, direct reading Weston dial instrument, and perhaps a like simple method of measuring inductances will come next. So great was the demand that his list now includes about 4500 different types and ranges of instruments.

Though the credit for developing the fundamental, typical Weston instrument was disputed for years, the patent courts have given sweeping decisions in his favor.

Dr. Hering then discussed at some length Weston's work on dynamo design, on illumination by the flaming arc and by electric incandescent lamps and concluded his address as follows:

Nothing was good enough for him if there was any possibility of improving it, and nothing seems to be too difficult for him to undertake. When the best manufacturers of this country or abroad, including the finest watch makers, found it too difficult to meet his exacting requirements for some of the parts of his instruments, he undertook the task himself. To beat the best gave him pleasure. When he wanted a wire drawn to half a mil in diameter he made it himself, as no manufacturer would undertake such a task. He wanted a screw thread of 500 to the inch, on a 10 mil rod; no one had come more than half way to this, but he accomplished it, originating the taps and dies himself. Not very long ago machine work to a thousandth of an inch was considered the highest class of work, but this was not good enough for Weston, who now works to the millionth, one thousand times finer.

A characteristic of his work is that he insists upon completely finishing a piece of work in the privacy of his laboratory, before it is brought before the public, which is in marked contrast with the more usual course of publicly proclaiming in the daily press the great things one intends to do, and which often never materialize. Instead of selling futures he sold finished products. His high ethical principles were shown when in the early days of incandescent lighting he insisted on the equity of rating the lamps by their mean spherical candle power, instead of deceiving the purchasers by measuring them in the direction of maximum light, as was not infrequently done by others.

Among his other early achievements may be mentioned the use of an arc furnace in 1875-6 for melting platinum and iridium, hence prior to Siemens, whose arc furnace is usually cited as the first. Dr. James Douglas, who was the first in this country to refine copper electrolytically on a large scale, credited his success to the advice and assistance of Weston in 1878, when very erroneous ideas about its practical impossibility were prevalent among others.

His personalitly only those of his personal friends who have had the good fortune to have been guests at his home and have been intimately associated with him, can truly appreciate. The same laudable extremes to which he aspires in perfecting his products, he shows in his kindness and loyalty to his friends and associates, as also in defending himself against his enemies. His high ethical principles have made for him both staunch friends and bitter enemies. To profit from losses to those who have shown confidence in his work is repulsive to him; what gives him pleasure is to please them.

On whatever balances a man's life work may be weighed, the scale of last resort for measuring it is the question, "In what way has the world benefited by his having lived in it?" The summary of his work, as given here to-night, will answer this.

The whole evening was very enjoyable, though the proceedings extended to a very late hour. The former recipients of the Perkin medal were Sir William Perkin, J. B. F. Herreshoff, Arno Behr, E. G. Acheson, C. M. Hall, H. Frasch, James Gayley and J. W. Hyatt.

Pyritic Smelting at Mount Lyell

At a recent dinner of the New York section of the Mining and Metallurgical Society of America, Mr. **Robert Sticht**, general manager for the Mount Lyell Mining & Railway Co., Queenstown, Tasmania, spoke informally of his experience in pyritic smelting in that country during the past 20 years. His remarks were discussed in an interesting manner by several members of the Society. Mr. Sticht said in part:

"As regards smelting, when I arrived at Mount Lyell the pyrite method was still a problem. I had enjoyed opportunity to carry it out in its purity, for short periods, whenever the ores were suitable, in Montana and Colorado, and had no fear, on an empirical basis, that it would not be possible to carry it on continuously where the ore was so favorable as at Lyell. But, for my own satisfaction in fully understanding what went on inside of a furnace, I was made general manager too soon. I then had to look after the pounds, shillings and pence, and investigations of metallurgy, as such, had to be postponed.

"Briefly, we started with three blast furnaces in 1896 and then installed converters. This plant was gradually enlarged to six blast furnaces. A second plant was built with five furnaces. When we abandoned hot blast, after six years' use, we pulled down the first plant and did all the work in the second. This plant received an extra furnace in the course of time, so that it has six, but we usually run only three furnaces. The most interesting development, perhaps, was the discarding of hot blast. I do not think I would now recommend it under any conditions.

High Ore Column and Blast Pressure

"Our furnace column reaches 18 ft. above tuyeres, and we use 64 oz. blast pressure. We base our work on the assumption that the inside of a furnace is occupied by a honeycombed mass of quartz, the passages of which are traversed by the blast and the molten sulphide, in opposite directions, the incandescent silica effecting simultaneous oxidation of the latter, by the oxygen of the blast, and the union of the FeO, thus formed, with the silica itself. This forms the slag, while the unoxidized portion of the sulphide makes the matte. Our matte runs from 45 to 50 per cent., rarely under 35 per cent., and sometimes as high as 60 to 65 per cent. (a 20:1 concentration). When the matte becomes too high, we reduce the siliceous ore; when too low, we increase the latter. The proportion of pyrites in the charge is constant; also the limestone. The only variables are siliceous ore and coke, but the latter is changed much less frequently than the former.

"As regards the percentage of coke used, I regret to say that the time when we got along with only 1½ per cent. (and sometimes as little as 1/10 per cent., with hot blast) is now merely historic. We are now under the necessity of smelting more of the siliceous ore, and, at the same time, the iron and sulphur in the pyritic ore have diminished, owing to the inclusion of a little galena and zinc-blende and a little more gangue. As a consequence, we now employ from 3½ to 5 per cent. coke, figured on the materials charged (except coke). The coke is our own make, but high in ash, and wet from the rainfall, which is 110 in. annually. Our slags are also more siliceous than they used to be, averaging 35 to 37 per cent. SiO_2 as against 30 to 32 per cent. in the past. The campaigns used to be three months or less; now they are a good deal longer, easily six months, the stoppages being caused by leaky jackets or the forehearth.

"Concerning shape of bosh, I am unable to see that it makes any difference. The furnace creates its own

internal lines, which may be entirely different from those of the designer. One can alter the position of the smelting zone, i. e., the focus, by changing the blast. The focus can be driven up by increased blast, in fact it may be driven clear to the top of the column.

"You might think our works old-fashioned. We have kept fully in touch with all modern improvements and tendencies in the United States, but have not found that we could advantageously make use of the most striking ones. This is true as well of economic as of purely metallurgical points. Each furnace is run individually as regards momentary composition of charge, and the principal factor in their operation is the feeding. We have to be very particular about this, and cannot resort to mechanical appliances intended to serve unchanging average conditions of feed, because our process is so sensitive to variations in the relative proportions of silica, sulphide, and air, and to the physical way in which these three come together. You cannot run a number of pyritic furnaces all in the same manner and obtain our present grades of matte with satisfactory constancy. You would have to reduce the grade to, say 20 per cent., and be satisfied to re-treat this."

Mr. D. H. Browne called attention to the fact that the practice outlined by Mr. Sticht was not applicable to all ores which contain sufficient iron and sulphur to smelt them. Sudbury ores, for example, containing 35 per cent. iron and 20 per cent. sulphur, are theoretically amenable to pyritic treatment, but many attempts had been made without success.

Experience at Tennessee Copper Company

Mr. J. Parke Channing said: "About 15 years ago, when I was starting the operations of the Tennessee Copper Co., I heard of what Mr. Sticht was doing at Mount Lyell, in Tasmania, and Mr. Frank Klepetko kindly laid my problem before Mr. Sticht. He advised me that I had better not begin with pyritic smelting in Tennessee, but stick to heap roasting. We spent $70,000 putting in roast yards, then smelted the ore with 13 per cent. coke, making a 40 per cent. matte in the first operation, which was then converted. We made money, and everyone was satisfied. I fear that if we had started on pyritic smelting I might have made a failure of it.

"Shortly after this, Mr. Freeland, manager of the Ducktown Sulphur, Copper & Iron Co., whose property adjoined that of the Tennessee Copper Co., began pyritic smelting. At first his slags were too siliceous, and to correct them he tried adding iron ore. This only made matters worse; and eventually, after pounding away at it and trying all the various combinations, he found that what was necessary was to cut down the coke and add silica. To him is due the credit for the pioneer work in pyritic smelting in the Ducktown district.

"Having the benefit of his experience, I took one of our 56x180-in. furnaces, ran the ordinary roasted-ore charge down low, filled it up with the pyritic charge, with a minimum amount of coke, and the furnace ran perfectly. We found, however, that it did not make much better than 10 per cent matte, which was then concentrated in a second furnace and bessemerized. We were soon able to clean up the roast yards and operate entirely by the pyritic method. Incidentally, we noted an increased extraction, as apparently some inexplicable loss ocurred in the roast yards, which we were never able to trace. We were never able to reduce the coke so far as Mr. Sticht did, nor were we able continuously to get so high-grade matte as he. As the furnaces are now operated, the question of matte-fall is of secondary importance, the most important object being to produce a gas which can be used in the acid chambers for the production of sulphuric acid.

"The present aim is to yield a gas which will run about 6 per cent SO_2 and 9 per cent free oxygen, so that there may be enough oxygen to convert the SO_2 to SO_3 in the chambers. If the SO_2 is high, and the oxygen low, it will not do to add atmospheric air, because of the large amount of nitrogen thereby introduced, which dilutes the SO_2 below working requirements. The best way is to keep the coke down to a small amount so that too much of the free oxygen will not be consumed in burning this carbon.

"For many years I had maintained to Mr. Browne that there was no reason why he should not smelt the Sudbury ores pyritically. He haunted the works of the Tennessee Copper Co. for over a year, trying to learn how to do it. About two years ago he engaged Mr. George A. Guess, who had been in charge of the Tennessee smelter, to try the experiment at Copper Cliff. Mr. Guess was given a furnace and blowing engine, and any kind of ore and flux that he wanted. After about three months I received two letters in the same mail; one from Mr. Browne saying that Mr. Guess had given it up, and the other from Mr. Guess himself saying that he could not smelt the ores pyritically and did not know why.

"I have grave doubts whether nickel-copper ores can be smelted pyritically. Possibly there is some peculiar characteristic of the nickel sulphide which prevents the pyritic action from taking place. In addition, a large amount of the silica in the Sudbury ore is combined as a bisilicate, and the conditions in the furnace are not suitable for breaking up this combination. There is just a possibility that in a very high furnace the desired result might be obtained, though I am of the opinion that Mr. Browne will have to continue with his roast heaps, for the present at least. There is a possibility that in the Knudsen furnace the problem may be solved. There, none of the material can get away, and possibly the complicated reactions may take place."

Action of Pyrite and Pyrrhotite

Mr. Sticht was asked whether the difference in the action of the Australian and Sudbury ores might not be due to the fact that the former was a pyrite and the latter a pyrrhotite, the extra atom of sulphur in the former exercising a favorable influence on pyritic treatment. In reply, Mr. Sticht said that he believed there was a strong misconception regarding the utility of the extra atom of sulphur in pyrite as a source of heat in the pyritic process. This extra atom is not burned, but is distilled. The FeS_2 turns practically to pyrrhotite at once, and even to something like Fe_5S_6 or Fe_3S_4 in the lower part of the furnace, and it is this particular sulphide which supplies the heat. In many ways, I think, a pyrrhotite ore is probably easier to smelt than a pyrite ore, but I may repeat that the most essential condition for the process is to have *free* SiO_2. What experience I had with pyrrhotite ores in Colorado made me feel that they were easier to treat than pure pyrites. In addition to keeping the throat more free, they seem to run hotter. But it was necessary not to be afraid to reduce coke, i. e., to a minimum which would ordinarily seem dangerous.

"One ought to have several feet leeway in the height of his smelting column. In reconstructing the Mount Lyell works, I raised the charge floor eight feet above the former one. A separate blower for each furnace is desirable if one can afford it, but that is only a minor point when there are not too many furnaces. When formerly using hot blast, the stoves standing between

blowers and furnaces, it complicated matters to have a blower for each furnace, and we did not do that at Mount Lyell. Our practice now is to supply about 20,000 cu. ft. of cold, free air per minute to each furnace. The 64 oz. pressure is only an incidental feature of the blast, and is due merely to the resistance encountered in forcing a given volume of air through a certain size of tuyere in a given time. Roughly speaking, it is volume rather than pressure that counts.

No Oxygen in Furnace Gases.

"Regarding the composition of our furnace gases, since the figures were first published, we have occasionally repeated the analyses, and still find practically no oxygen in the gases leaving the furnace, nor at a depth of 7½ ft. below top of the column. The determinations were last made a few months ago, with a water-cooled apparatus."

"The furnaces at Mount Lyell appear to be running with hot tops. This is due to the large amount of sulphur distilling off, which burns as it comes in contact with oxygen of the air above the charge. It is possible to run the furnace on matte and pyrrhotite with a satisfactorily cold top. On pyrites, however, this is impracticable, for this low temperature can be achieved only by operating in a manner which leads to rapid formation of crusts around the throat. We run, therefore, so as to avoid crusts, and thus appear to have a fiery throat. One must, however, not contemplate the combustion of the sublimated elemental sulphur, but judge throat conditions rather by the phenomena at the top of column. The top of the furnace is really not hot, for the pieces of charge glow slightly only around the walls, and are black and cold over the full inner area of the top. Between these cold pieces a whitish flame is visible, which changes into a heavy cloud of sulphur vapor a foot or two above the top of charge; this then ignites and forms the usual dense white smoke characteristic of the work. The furnace acts as its own crusher; all materials are charged in as massive lumps as the men at the mines and quarries can readily handle. Possibly, if we crushed them first, they would so decrepitate in the furnace that the latter would choke tight, and we could not practice pyritic smelting."

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Improved Cam for Stamp Mills.—In the December *Bulletin* of the A. I. M. E., Mr. Arthur B. Foote describes an improved form of cam which he has used at the North Star mill in California.

"The cam at present in use lifts the tappets with an involute form of curve, to which the surface of the tappet is always tangent. Moreover, the line of contact between tappet and cam, if produced, would pass through the center of the stamp. While this is a desirable feature, the inventor had believed that it would be more desirable if the cam were to pick up the stamp without shock, and gradually increase the upward velocity throughout its movement. The involute cam attempts to impart instantly a high upward velocity to the stamp, starting it from a state of rest, and the result is a destructive blow, a good deal of noise, and much wear and vibration.

"The new form is one which is designed to lift the stamp with a motion similar to that of the piston of an engine between the end and middle of its stroke; in other words, harmonic motion, from the point of zero to maximum velocity. The curve will give this ideal motion only when the stamp is set for the exact drop for which the cam was designed, but the improved cam will not be as bad as the involute until the drop is reduced one-half. In other words, if a cam is designed for a 6-in. drop, it will be some improvement over the usual form of cam until the drop is only 3 inches.

"Any cam, of course, must lift its stamp in the same number of degrees of revolution, and therefore this new form, starting the stamp slowly, must end up by going faster, the average speed being the same. With this design, the surface of the tappet is not tangent to the surface of the cam throughout the lift. The possible consequences of this were studied with a full-sized model, and did not seem serious, since the engagement between the surfaces was an easy sliding motion instead of a blow. If the drop is shortened, the blow becomes more and more pronounced, but the surfaces also become more and more nearly tangent.

"Five cams of this design have been running in one of the mills of the North Star Mines Company for over a

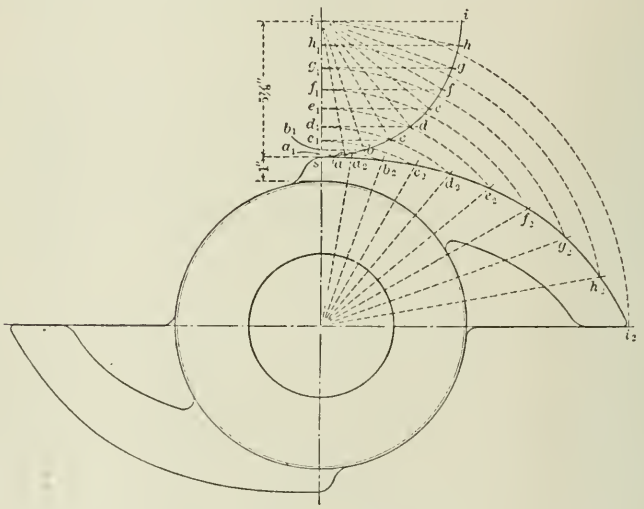


FIG. 1—IMPROVED CAM

month, fulfilling every expectation. Holding the hand on the tappet it is impossible to feel the cam strike it, although the mill is running 107 drops per minute.

"The accompanying drawing, Fig. 1, shows the method of laying off the curve of the cam, which will give approxiately harmonic motion to the stamp. The spaces sa_1, a_1b_1, b_1c_1, etc., represent the distances traveled by the cam in equal intervals of time."

Acid Treatment of Gold Precipitate.—Some practical notes on this subject are offered by Mr. H. A. White in the September, 1914, *Journal* of the Chem. Met. & Min. Soc. of S. Africa. The use of sodium bisulphate is becoming general in place of commercial sulphuric acid. This material is obtained as a by-product from dynamite factories, and contains from 28 per cent to 40 per cent sulphuric acid. Its use shows a saving over commercial acid.

"Where white precipitate is present in the boxes in considerable quantity, special precautions are advisable in the acid treatment. These include (a) emulsification of the white product taken from the filter press and the avoidance of the formation of greasy lumps which are very slowly acted upon by the acid. (b) Owing to the fact that the action of sulphuric acid is somewhat slow (especially in the presence of ferrocyanides) it is advisable to allow at least twelve hours' contact with hot acid in excess and to reserve some of the coarser zinc shavings, to be dissolved, for subsequent neutralization of the remaining acid. A considerable improvement in the value of the calcined slime is easily effected in this way."

The corrosion of the clay liners used in crucibles is observed to increase rapidly in the vicinity of cracks. In order to avoid the formation of these cracks it is essential that the liner should be evenly supported and heated. To attain this object it is well to fill the space between the liner and pot with powdered graphite, using crushed crucibles for this purpose. Liners supported in this manner will give up to 50 per cent more fusion than usually obtained.

"On some mines it is not found necessary to add any flux or oxidizer whatever to the well-calcined gold slime as it is self-fluxing and contains sufficient ferric oxide to keep the value of the bullion produced well above the level of the usual battery bars. The slag thus produced is fairly low in gold, but owing to unavoidable variations in the composition of the calcined slime, even on the same mine, trouble may be caused by insufficient fluidity of the slag or by undue corrosion of the liner.

"A method allowing a little more elasticity in conditions is to fill the liner within ½ in. with the gold slime and to pour on this, as a protective cover, a mixture of 1½ parts of fine sand and 1 part (by weight) of calcined borax. This may amount to 15 per cent or 20 per cent by weight of the calcined gold slime, and gives a fluid non-corrosive slag at a reasonable heat. I would suggest that preliminary experiments in this direction be made with two of the pots in a "pour," as any trouble can easily be rectified (by adding borax or otherwise) in the next melt, and the conditions are strictly comparable.

"It is clear from comparative experiments made with slime ranging in value from 10 per cent to 35 per cent of bullion that, as Mr. Dowling has pointed out (*Rand Metallurgical Practice,* Vol. I, p. 271, and *Chemical, Metallurgical and Mining Society's Journal,* Vol. VII, p. 212, January, 1907), the intimate mixture of flux and slime is not necessary, and this practice, which is conducive to loss of valuable dust, should by now be completely obsolete.

"By the above methods the value of the gold slag produced (after panning) may be reduced below 10 oz. per ton, and as the quantity is smaller the total value of such by-products as pots, liners, and slag should not exceed ½ per cent of the cyanide gold produced, and, in fact, in some cases is below ¼ per cent, while the buttons of gold from each pot have averaged over 100 oz. for some clean-ups. In this manner also a considerable saving in cost is shown."

Determining Dissolved Gold in Slime Residue.—Since vacuum filtration of slime became common practice, it has become increasingly necessary to know definitely the gold content of slime residue in order to regulate the dissolving and washing periods and secure the highest economic extraction. In a paper published in the monthly *Journal* of the Chamber of Mines of Western Australia Mr. L. R. BENJAMIN discusses the methods for determining the proportions of soluble and insoluble gold in filter residue, and points out possible errors in the work.

One method is to filter and assay the solution in the residue, and calculate the equivalent of dissolved gold from the percentage of solution to dry slime. The value thus obtained is then deducted from assay value of dried residue, giving the undissolved equivalent. Another method is to assay the dried residue for total gold; assay the water-washed residue for dissolved gold and get the undissolved equivalent by difference.

The author discusses the possibility of gold losses by either of these methods and finds two periods in the operation when high temperatures may cause loss of gold and affect the accuracy of the work. The first period is in the drying of the sample over a fast fire, when he finds that capillary attraction may cause a segregation of gold into a scale adhering to the pan. The second is during the assay fusion.

He found air-drying to yield higher results than fire-drying, but requiring a longer time for the work. In order to minimize the losses in rapid drying he suggests precipitating the dissolved gold prior to drying, and finds that the use of a 5 per cent cuprous chloride solution gives excellent results. As for fusion losses during assaying, he comes to the conclusion that they are "anything but a bogey," and always occur, varying directly with the amount of gold remaining in the combined state after drying, and due probably to volatilization.

Copper Smelting.

Coal-Dust Fired Reverberatory Furnaces.—In the January *Bulletin* of the American Institute of Mining Engineers there are two papers on the development and use of coal-dust firing for reverberatory copper smelting. The first, by Mr. D. H. BROWNE, reviews the history of the method and its adoption at the works of the Canadian Copper Company; the second. by Mr. L. V. BENDER, gives results obtained by the Anaconda Copper Company.

The use of reverberatory furnaces at the Canadian Copper Company's works was made necessary by increasing quantities of flue dust and fine green ore. When the practice was first considered, coal-dust firing was investigated and considered feasible. S. S. Sorensen had been the pioneer investigator in this line of work at the Highland Boy smelter in Utah, and had been followed by Charles Shelby at Cananea. Both had experienced trouble due to accumulations of ash as a blanket on the molten charge and in the throat of the furnace, but the trials indicated possible improvement in reverberatory smelting, particularly as regards fuel ratio. It was finally adopted at Copper Cliff, however, designing furnaces especially to meet the requirements by eliminating right-angled bends in the flues and placing the skimming door at the side instead of the end. The waste-heat boiler was made a secondary consideration. The first smelting showed no difficulty with the fuel, and as improvements were gradually made the smelting became more efficient. In the first three months of 1914 the fuel ratio was 5, 5.65 and 6.77, respectively. The method of feeding has been changed. At first it was done through hoppers near the fire end, but is now done almost entirely through pipes in the side walls. Coal dust is introduced through five pipes 5 in. in diameter. It is first dried and then ground so that about 95 per cent passes a 100-mesh and 80 per cent passes a 200-mesh screen. The great advantage found in this method of firing is the absence of breaks in the temperature curve due to grating or cleaning the hearth, and as a consequence a greatly increased tonnage and fuel ratio.

At Anaconda coal-dust firing was tried in June, 1914, in a furnace 124 ft. by 21 ft. The method of charging was similar to that used at Copper Cliff. From the experience gained in this work, Mr. Bender lays down the following requisites for successful use of coal dust: (1) The coal should be dried before pulverizing, containing not more than 1 per cent moisture; (2) fine pulverization affords increased area and higher thermal efficiency, 95 per cent should pass a 100-mesh screen and 85 per cent a 200-mesh; (3) the quantities of coal and air delivered to the furnace should be carefully controlled in order to secure complete combustion; (4) the coal should contain enough volatile combustible matter to give the required combustion, a standard for cement work is 30 per cent; (5) the furnace should be properly designed and equipped, and (6) provision must

be made for taking care of the ash. Based on past experience, some changes will be made in the new equipment for coal-dust reverberatory firing at Anaconda. The furnaces will be 144 ft. by 25 ft., with a flue area of 48 sq. ft. Matte will tapped at the front. The skimming plate will be 12 in. higher than in other furnaces, the top of the plate being 24 in. above the tap hole. Recent records for a week at Anaconda indicate the efficiency of coal-dust firing; the average tonnage per day was 542.7, with a fuel ratio of 7.5.

Concentration.

Flow of Sand and Water Through Spigots.—It is common practice in ore-dressing operations to pass pulps of sand and water through spigots, as in jig hutches, classifier pockets, etc. "With a given quantity of solids per unit time, of a given specific gravity, to be discharged with water under a given head, and with a given rato of water to solid, what must be the size of the spigot opening?" Such is the nature of a problem investigated by Prof. R. H. Richards, of Boston, Mass., and Mr. Boyd Dudley, Jr., of State College, Pa. Their results are published in the January *Bulletin* of the A. I. M. E. If a spigot is to be opened continuously, there are, aside from its form, three factors governing the rate at which it will discharge a given mixture, viz., the head of water above the spigot, the area of the spigot opening and the viscosity of the material discharged. By the term viscosity as used here is meant the ratio of the volume of pure water that will flow through a given orifice under a given head in a given time to the volume of the material under consideration that will flow through the same orifice under the same conditions.

The head of water above a spigot is usually fixed; so with the head known, in order to determine the size of the spigot required, it is necessary to know the viscosity of the desired mixture, and the coefficient of discharge of the form of spigot employed when pure water is discharged. From these data the area of the spigot can be calculated from the equation

$$a = \frac{fq}{c\sqrt{2gh}}$$

in which a is the area of the spigot opening, f being the viscosity of the mixture, q the rate of discharge by volume, c the coefficient of discharge, g the acceleration due to gravity and h the head of water above the spigot. The coefficient of discharge is the ratio of the actual rate of discharge of pure water to the theoretical rate as calculated from the effective head above the spigot. The value c for forms usually found in classifier spigots under heads of from 1 to 3 ft. is between 0.87 and 0.91, the higher values for lower heads.

The authors studied the relation between the composition and viscosity of sand-water mixtures. The sp. gr. of the sand was 2.72. Experimental results are given in the table.

Relation of Composition to Viscosity of Mixtures of Sand and Water

Kilos sand and water	Kilos sand	Kilos and litres water	Litres sand	Litres sand and water	Per cent sand, vol.	Per cent sand, weight	Viscosity mixture
9.20	0.00	9.20	0.000	9.20	0.00	0.00	1.00
9.30	0.45	8.85	0.165	9.02	1.83	4.84	1.02
9.35	1.10	8.25	0.405	8.66	4.68	11.8	1.06
9.35	1.40	7.95	0.515	8.47	6.08	15.0	1.09
9.40	1.90	7.50	0.699	8.20	8.53	20.2	1.12
9.40	1.95	7.45	0.717	8.17	8.78	20.8	1.13
9.55	2.20	7.35	0.809	8.16	9.92	22.0	1.13
9.20	2.25	6.95	0.827	7.78	10.6	24.4	1.18
9.05	2.50	6.55	0.920	7.47	12.3	27.6	1.23

It was found by these tests that when the amount of the sand in the mixture exceeded 30 per cent by weight, the spigot would produce a very thick discharge for a short time, but that continuous operation under these conditions was not certain, and clogging would result.

A concrete example illustrating these data is given. It is desired to discharge from the pocket of a classifier 40 tons of sand per 24 hours, together with water in the ratio of 1 sand to 3 water, by weight. The head of water above the spigot is 3 ft. The mean sp. gr. of the sand is 2.81. What must be the diameter of the spigot opening? The area of the opening can be calculated from the formula given.

Taking up the terms on the right hand of the equation is order, f, the viscosity, may be estimated as follows: The weight-ratio of water to sand in the mixture to be discharged is 3 to 1. Considering 100 g. of the mixture, the weight of water is 75 g.; its volume is 75 cc. The volume of the sand is 25 g. $\div$ 2.81 (the density of the sand) = 8.9 cc. The total volume of 100 g. of the mixture is 75 + 8.9 = 83.9 cc. Hence, the percentage of sand by volume in the mixture is 8.9 $\div$ 83.9 = 10.6. From the table the viscosity of a mixture containing 10.6 per cent of sand by volume is 1.17. Therefore $f = 1.17$.

The quantity of sand discharged per 24 hr. is 40 tons. One ton per 24 hr. is 0.631 kg. per minute. Forty tons per 24 hr. is $40 \times 0.631 = 25.2$ kg. per minute. The volume of sand per minute is 25.2 $\div$ 2.81 (the density) = 8.98 liters. The quantity of water per minute is three times that of the sand, $25.2 \times 3 = 75.6$ kg. = 75.6 liters. The total volume of sand and water per minute is 8.98 (sand) plus 76.5 (water) = 85.5 liters. The total volume per second is 85.5 $\div$ 60 = 1.43 liters = 1,430 cc.

Since the spigot is to consist of a short tube with a cone mouth on the influx end, the coefficient of discharge, c, may be assumed as 0.88.

In metric units $g = 980$ cm. per sec.^{2}; and the head, h (3 ft.), is 914 cm.

Substituting these values in the above equation gives, for the area of the spigot opening.

$$a = \frac{1.17 \times 1430}{0.88\sqrt{2 \times 980 \times 914}} = 1.42 \text{ sq. cm.}$$

The diameter may be obtained from the relation,

$$d = 2\sqrt{\frac{a}{\pi}} = 1.35 \text{ cm.} = 0.53 \text{ in.}$$

Recent Chemical and Metallurgical Patents

Iron and Steel.

Briquetting Fine Ore.—According to the specifications of a patent of Wilhelm Schumacher, of Osnabrück, Germany, the compression of finely divided iron ore, in which the iron is in a low state of oxidation, together with a catalytic agent such as calcium chloride, effects the conversion of the iron compound into a higher state of oxidation, and produces briquets suitable for use in the blast furnace. The inventor has observed that when flue dust, containing the lower order of iron oxides, is briquetted with a catalytic agent, sound briquets are produced; and further the iron becomes oxidized. In the light of these facts, he proposes to briquet fine iron ores by first reducing them with coal dust, then mixing with lime if necessary, and briquetting. The mixture of ore and coal is heated to 500° or 600°C.; or to a lower temperature, say 400° to 500°C., at which temperature it may be treated with gases containing carbon monoxide. In either case reduction occurs, and the product is ready for mixing and briquetting. If the last process is performed at great pressure, the admixture of a catalytic agent may be entirely unnecessary. (1,121,048, Dec. 15, 1914.)

Furnace for Heating Billets.—A special type of furnace for heating billets or ingots preparatory to rolling, is patented by Mr. JEROME R. GEORGE, of Worcester, Mass. The furnace consists of a long channel, at one end of which the billets are introduced sideways and caused to travel to the opposite end, where they are removed. Heating gases enter the furnace at the discharge end, and are directed under and around the billets in a manner that gives high fuel efficiency. Near the discharge end of the furnace, the floor is inclined downwardly to facilitate the collection and removal of cinder, slag and molten metal that drips from the billets as they become highly heated. (1,121,621, Dec. 22, 1914.)

Liquid Fuel for Furnaces.—A new process of generating heat, particularly applicable to the melting of metals and smelting of ores, is patented by Mr. BRADLEY STOUGHTON, of New York City. The essential features are the use of fluid fuel to supply all or practically all the heat needed, and the use of a minimum quantity of solid fuel, the function of which is to be maintained incandescent for the purpose of igniting and insuring complete combustion of the fluid fuel without waste. Sufficient air is admitted to insure complete combustion of the fluid fuel and to keep the solid fuel incandescent, it being an object to consume the latter as slowly as possible. The process may be applied to shaft furnaces and some forms of reverberatory furnaces. A heated blast of air may be used, and steam for atomizing the oil. The process may be applied by placing at the bottom of a furnace a thin bed of coke, on this a layer of ore or metal, then a layer of coke, and so on. The coke bed is then ignited and the oil injected into the incandescent mass with sufficient air to insure complete combustion of the oil and incandescence of the coke. (1,117,274, Nov. 17, 1914.)

Making Manganese Steel from Scrap.—In a patent recently granted to Dr. HENRY M. HOWE, of Bedford Station, N. Y., he discloses a method of remanufacturing manganese steel scraps into manganese steel articles in which the necessary critical relation between the proportions of carbon, manganese and iron are maintained. In brief the process consists first in melting and mixing scrap and manganiferous material, such as commercial ferromanganese, in suitable proportions to produce the critical ratio between carbon and manganese in the mixture, with a suitable allowance for the changes in the proportions of these elements which will take place from the reactions incident to melting. In other words, the proportions must compensate for the loss of manganese by oxidation and the gain in carbon by absorption from the fuel. Having established this ratio, the mixture is diluted with carbon-free iron, such as blown Bessemer metal, until the amounts of carbon and manganese bear to the whole the desired percentage relation. The final adjustment of proportions may be made in an open-hearth furnace. (1,117,384, Nov. 17, 1914.)

Removing Rings from Nodulizing Kilns.—In order to remove rings of slagged material accumulating in rotary kilns used for nodulizing iron ores, Mr. FRANCIS B. DUTTON, of Lebanon, Pa., proposes to introduce water under pressure against the surface of the adherent ring. According to the patent specifications this is accomplished by arranging a series of water pipes along the length of the kiln, said pipes being connected with a header and extending through the kiln wall. Water introduced through these pipes under pressure would come in contact with the surface of the hot slagged mass, and by the sudden generation of steam, as well as by the force of the water, the accumulation would be dislodged. The operation is performed in a short space of time, does not allow the kiln to cool to a substantial degree, and eliminates the application of manual labor to the removal of the rings. (1,117,814, Nov. 17, 1914.)

Gold and Silver.

Filtering Apparatus.—Two types of filtering apparatus for slime have been patented by Mr. O. J. SALISBURY, of Salt Lake City, Utah. The first is a filter press consisting of a casing of circular cross-section, and containing the filter leaves or elements suitably connected with a source of vacuum. In order to facilitate the inspection of the press and the discharge of the cake formed on the leaves, the casing or shell is formed of similar sections hinged along an upper median line, and capable of opening and closing in unison. When in the closed position the sections are locked to make a liquid-tight joint. In operation the casing is charged with slime, under pressure, and the filtered liquid passes through the leaves and suitable connections to an outside receiver. The cakes thus formed on the filters are discharged by opening the hinged sections of the casing. (1,120,628, Dec. 8, 1914.)

The second type of filter is cubical in form, the casing consisting of two sides and ends rigidly connected, while two of the sides are designed for removal to form a clear passageway through the casing for the unabstructed discharge of the filter cakes. The casing contains filter leaves or elements suitably connected through a header with an outside receiver. The removable sides are rotatable about the casing, and the entire apparatus may be rotated to bring it into a position for discharge. In both types of apparatus the cakes are formed and washed by hydraulic pressure, and discharged by reverse pressure of a fluid in the filter leaves. (1,120,629, Dec. 8, 1914.)

Copper and Cobalt.

Copper Leaching and Electrolysis.—A hydrometallurgical process for copper sulphide ores patented by Mr. N. V. HYBINETTE, of Christiania, Norway, consists in roasting the ore to a point beyond the formation of Cu_2S but not to complete oxidation, leaching with sulphuric acid and precipitating by electrolysis. The ferric iron salts in the solution are used to dissolve the sulphide of copper remaining in the ore due to incomplete roasting. The inventor states that the disturbing influence of ferric salts on the deposition of copper does not occur before the amount is above 10 gr. ferric iron per litre, and the process does not become practically impossible before the amount rises above 15 gr. per litre. The rapidity of oxidation of the iron salts depends on the amount of ferrous iron in solution, proceeding with almost theoretically rapidity as long as there is present not more than 30 gr. ferrous iron, but ceasing as long as there is only 15 gr. ferrous iron. Therefore as long as there is not much more than the 30 gr. per litre present, the oxidation of iron above 15 gr. per litre as ferric sulphate goes forward very slowly, and the dissolving of the cathodes does not present unsurmountable difficulties at that degree of concentration of ferric salts. At the same time he has found that most of the copper sulphide in the roasted ore is readily soluble in a solution containing 15 gr. iron as ferric sulphate, but insoluble if the concentration falls below 10 gr. per litre. Therefore, by holding the iron content at a concentration of about 30 gr. per litre, the process may be successfully conducted.

The ore is roasted so that about 25 per cent of the copper is present as sulphide, insoluble in 5 per cent sulphuric acid solution. A solution containing about 30 gr. iron and 20 gr. copper as sulphates, and 60 gr.

free sulphuric acid per litre, is circulated between the electrolytic cells and the leaching vats. The solution entering the cells is regulated to contain about 30 gr. per litre, and leaves with about 20 gr. The solution entering the cells contains about ferric iron in quantity from 2 to 5 gr. per litre, and about 15 gr. on leaving. Thus about 10 gr. copper is plated and about 10 gr. iron oxidized. The success of the process depends on roasting the ore to the correct point, and in maintaining the proper amount of iron in solution. The latter is regulated by periodically discarding some of the solution. (1,122,759, Dec. 29, 1914.)

Electrolytic Production of Wire.—An invention relating to the production of copper wire by electrodeposition and drawing, is patented by Mr. William E. Gibbs, of Plainfield, N. J. It has for its object the production of a wire of high electrical conductivity and of superior quality due to the exclusion of impurities occurring in the ordinary drawn wire. The wire is carried automatically through electrolytic vats containing an electrolyte of about 3.5 per cent copper and 10 per cent sulphuric acid at a temperature of about 140 deg. F. (1,120,191, Dec. 8, 1914.)

Reduction of Cobalt.—The reduction of cobalt and similar metals from combinations with arsenic, sulphur and similar metalloids may be accomplished according to a patented process of Dr. Colin G. Fink, of Schenectady, N. Y. He mixes the ore with a reaction mixture which, upon heating, yields a metal having a higher heat of combination with non-metallic elements than that of the metal which is desired to recover. Such a mixture is calcium carbide and calcium oxide, yielding calcium and carbon monoxide. The liberated calcium combines with the metalloid of the ore and liberates the metal. Thus, in the case of cobalt in smaltite

$$2CaO+CaC_2=3Ca+2CO$$
$$CoAs_2+3Ca=Ca_3As_2+Co$$

The process is conducted in a vacuum furnace at a temperature as high as 1500 deg. C. (1,119,588, Dec. 1, 1914.)

Lead and Zinc.

Bag House for Lead Smelter.—Mr. Willard E. Playter, of Collinsville, Ill., has patented apparatus for controlling bag-house operations, causing them to occur automatically in proper sequence. The apparatus is electrically operated and controls the supply of gas and means for shaking the bags. The essential features of the apparatus are a motor and a drum controller provided with contact members. As the drum revolves the contact members cooperate with brushes in circuit with solenoids controlling air valves. These valves operate the dampers that open or close the ports between the flue and the bag-house units, admitting or excluding gas from any unit. They also control the shaking means, which consists of an air chamber above each bag and a depending flexible tube or hose within each bag. When air is admitted to the chambers and passes through the tubes, it causes the latter to vibrate with considerable violence and shake the accumulated dust from the bags into the cellar beneath. The apparatus may be adjusted as regards time so that the different operations occur in proper sequence at stated intervals. (1,118,045, Nov. 24, 1914.)

Electric Zinc Furnace.—A zinc furnace of the resistance type has been patented by Mr. Otto E. Ruhoff, of Madison, Wis. The furnace has a number of charge openings distributed along its top, a set of electrodes at the top in contact with the charge and a corresponding set of electrodes at the bottom. The walls of the furnace are provided with a relatively large number of condensers so that condensation can be accomplished quickly. (1,121,874, Dec. 22, 1914.)

Recovery of Zinc from Waste Liquors.—The extraction of zinc from liquor containing ferrous iron, as in the case of liquors from which copper has been precipitated by means of iron, is patented by Dr. Wilhelm Buddeus, of Charlottenburg, Germany. Both the zinc and iron are precipitated by means of lime, filtered and dried. During the drying process the ferrous iron is oxidized to ferric oxide, and from the resulting product the zinc may be dissolved by means of acid. The quantity of acid used is regulated by the amount of zinc in the mass. The resulting leach liquor is separated and treated as desired to recover the zinc. (1,120,683, Dec. 15, 1914.)

Electrical Precipitation of Suspended Matter

The corona discharge is utilized to precipitate suspended matter from gas, according to specifications of a patent granted to Messrs. William W. Strong of Pittsburgh, and Arthur F. Nesbit, of Wilkinsburg, Pa. The patent is assigned to R. B. Mellon, of Pittsburgh. The effect of the introduction of a spark gap in series with the active or grounded electrode is to extend the luminous region about the active electrode, and this fact is used in connection with the separation of suspended matter from a gas. (1,120,561, Dec. 8, 1914.) Apparatus that will throw on the high tension electric current used for such separation, only when suspended matter of a certain density exists in the gas, is the subject of a separate patent granted to Mr. William W. Strong. (1,120,560, Dec. 8, 1914.)

Electric Treatment of Emulsions and Dusty Gases

Petroleum emulsions can be freed from water by treatment in an electric field in suitable apparatus. The potential between electrodes is maintained sufficiently high to positively cause a puncturing of the oil between the different particles of water, so that they coalesce in a practically continuous chain between the electrodes. When the current is interrupted, the chains coalesce into a globule of water which then drops out of the oil. The patented apparatus and method are illustrated in the specifications. (1,116,299, Nov. 3, 1914.)

The electric precipitation of dust or suspended particles in a gas is patented by Messrs. W. W. Strong, of Pittsburgh, and A. F. Nesbit, of Wilkinsburg, Pa. The patent is assigned to R. B. Mellon, of Pittsburgh. The electrode maintained at a high difference of potential. The grounded electrode is formed in the shape of cells through which the dust-laden gas is passed, and within which is placed the active electrode. The dust is precipitated onto the grounded electrodes or into deposition chambers. (1,119,469, Dec. 1, 1914.)

Metallurgical Furnace

A roasting furnace is patented by Mr. Utley Wedge, of Ardmore, Pa., being of the superposed-hearth type in which stationary hearths alternate with rotating hearths. The rotating hearths are attached to a central rotating shaft. Both the fixed and rotating hearths have depending rabbles attached, so that material fed onto any one of the rotating hearths will be moved outward and discharged over the edge of the hearth onto the fixed hearth below, when it will be moved inwardly to the central point of discharge onto the moving hearth below. (1,119,483, Dec. 1, 1914.)

The Foreign Trade Movement was the keynote of the convention held on January 21 and 22 by the National Foreign Trade Council at St. Louis. President Farrell of the Steel Corporation is the chairman of the Council. Upwards of 300 delegates were in attendance.

Notes on Chemistry and Metallurgy in Great Britain

(From our London Correspondent)

The War and Engineering Industries

Conditions have improved considerably during the last few weeks in the engineering trades generally. At Sheffield there has been a decided advance in almost all classes of work as well as the exceptional briskness due to increased output of war material; while important orders from the French Government are virtually secured. The demand for warlike stores maintains great activity in Birmingham works producing such material; but those not so employed are by no means so happily circumstanced. Very large orders for motor-bicycles have been placed, and over a thousand of these machines are being built for the Russian Government. In South Wales the iron and steel works are growing busier; and the output of railway rolling stock, galvanized sheets, nickel and copper has attained very large dimensions. In the northeastern district manufacturers continue to experience considerable difficulty in securing adequate labor to cope with the Admiralty and War Office orders.

Labor troubles have been threatening at Elswick, but so far the dissatisfaction of the men with certain new conditions has not led to any interruption of work, and the matter appears likely to be smoothed over. On the Clyde numerous contracts for cargo steamers have been placed, and the outlook is very satisfactory. Sir W. G. Armstrong, Whitworth & Co., of Newcastle, have secured the contract for three pairs of gates for the north basin and central dock entrances at West Hartlepool, the order for which material was originally given to a German firm at Oberhausen; and among other contracts transferred from German workshops is one for six locomotives for the Taff Vale Railway which has been placed with the North British Locomotive Company of Glasgow.

* * *

At a meeting of the Birmingham Chamber of Commerce on November 30, the chairman, Mr. Sambridge, said that most of the gloomy forebodings entertained at the beginning of the war had been entirely falsified, and, instead of industries being paralyzed, trade was in a very healthy state, and many firms were encountering great difficulties through shortage of labor. Of course, some trades had been rather badly hit, but even with these there was now an improvement. Closed markets must be replaced by others. There was a great improvement in the financial position with a gradual but steady re-establishment of credit, while exchanges were easier. War was necessarily wasteful, but they must not lose sight of the fact that a very large proportion of the sums of money which the country had to provide would be spent at home and would benefit our industrial population. The action of the Government with regard to aniline dyes might well be extended to other products with advantage to home manufactures.

The Prevention of Explosions in Mines

The Home Office committee on explosions in mines has issued its sixth and final report on the experiments which have been carried out during the last three years at Eskmeals. Three methods of preventing, or, at all events, greatly reducing the risk of explosions are recommended: (1) The maintenance throughout the roads of such a proportion of incombustible dust in a state of fine division as would make a mixture yielding on incineration at least 50 per cent of ash; (2) the maintenance of at least 30 per cent of water in a state of intimate mixture with the coal dust throughout the roads, and (3), a combination of methods (1) and (2), adding the water after the incombustible dust.

Charges of 24 ounces of blasting powder fixed from a cannon in the large gallery at Eskmeals had failed to cause ignition of a mixture of equal parts by weight of coal dust and incombustible dust when the gallery contained atmospheric air only, or when the air contained as much as 2.3 per cent of coal-gas; but when the air contained 2.5 per cent of coal-gas or sufficient firedamp (obtained from Cymmer Colliery, Glamorganshire) to yield 4.6 per cent of methane, the mixture of dusts was ignited, and flame traveled throughout the gallery. No ignition occurred when the air contained 4.5 per cent of methane. The lower limit explosive mixture of methane and air under ordinary conditions requires 5.6 per cent of methane. The efficacy of the incombustible dust appeared to depend more on the degree of fineness than on its composition, and unless the dust contains not much less than 50 per cent by weight of particles capable of passing through a 200 x 200 sieve more than one part of incombustible dust to one part of coal dust is required to prevent ignition. With reground Altofts shale and superfine dolomite dusts containing respectively 55 and 66 per cent of the stated degree of fineness one part to one part of coal dust was sufficient; with flue dust, 31 per cent 200 fine, and dolomite dust, 42 per cent 200 fine; 1½ part to 1 of coal dust was necessary, while three parts of sand, 4 per cent 200 fine, to one part of coal dust was found to be insufficient to prevent ignition.

With regard to watering, experiments conducted by the United States Geological Survey some years ago demonstrated that, in order to prevent propagation of flame, the coal dust must be admixed with about 30 per cent of water, and while this quantity does not produce a wet mixture with fine coal dust, 40 per cent of water produces a muddy mixture. Similar experiments have been repeated at Eskmeals, both with coal dust in its natural state and with mixtures of coal dust and incombustible dust, and the results confirm those arrived at in America. With mixtures of coal dust and incombustible dust the Eskmeals experiments went to show that the amount of water required to render the mixture non-inflammable varied inversely as the total ash of the mixture. The coal dust mixture containing 15 per cent of ash would require the addition of from 25 to 30 per cent of water to render it incapable of propagating flame, and each additional 10 per cent of ash in the mixture reduces the requisite quantity of water by about 5 per cent. The nature of the incombustible dust also has a decided effect. Shale dust absorbed moisture more readily than Fuller's earth and formed a binding material which had an agglomerating effect on the fine coal dust which remained caked after drying.

The committee arrived at the conclusion that a combination of "stone dusting" and watering is preferable to either method alone. The manner in which the water is applied to the coal dust has considerable influence on the quantity required. Mixtures prepared outside the gallery and then spread along it by the hand resisted ignition when 30 per cent of water was present; but the spraying of 30 per cent of water by means of jets or rose sprays on the dust strewn along the gallery would not be equally effective, because watering by such means only moistens part of the dust while most of it is swept from the ledges to the floor, forming pools of water and dry dust accumulation without admixture. But when atomizers, delivering the water as a fine mist, were used, it was established that coal dust moistened with an equal weight of water resisted propagation of flame for more than a short distance, even when the conditions of ignition were severe.

This report would be more satisfactory if it represented the unanimous opinion of all the members of the committee, but unfortunately two members, Professor Dixon and Mr. W. C. Blackett, who are not directly connected with the Home Office, have withheld their approval. Moreover, every practical man will recognize that there would be very great difficulty in uniformly maintaining the conditions recommended by the committee; and the protection afforded would not be continuously effectual.

Copper and Nickel

Application of Chloridizing-Roasting to Separation of Copper and Nickel.—The possibility of treating heavy sulphide ores, such as those of Sudbury, Ontario, containing much iron and small amounts of copper and nickel, by chloridizing and removing the copper, leaving an iron-nickel oxide product suitable for production of nickel-bearing iron by smelting in the blast furnace, has been investigated by Mr. Boyd Dudley, Jr., who presents some of his results in the December, 1914, *Bulletin* of the A. I. M. E.

The author first studied the reaction involving the production of chlorine from sodium chloride by the action upon it of sulphur trioxide and atmospheric oxygen. In the roasting furnace the sulhpur trioxide would be obtained from the decomposition of sulphates formed in roasting the ore, and the oxygen would be supplied from the air in contact with the roast. It appears from his experiments that the rate of reaction becomes appreciable at about 500 deg. C. and increases rapidly with rising temperature. The highest temperature attained was 769 deg. C. Another reaction studied was that involving the combination of sodium chloride, silica and oxygen, to form sodium silicate and chlorine. It was found that up to the temperature at which salt melts, 800 deg. C., salt was not decomposed to an appreciable degree.

Experiments were then performed on the chloridation of copper and nickel oxides, using mixtures of copper and nickel oxide with ferric oxide, silica, ferric sulphate and sodium chloride. With copper only it was shown that the completeness of chloridation increases with increasing temperature (500 deg. C. to 700 deg. C.) and increasing time (2 to 4 hours). Considerable copper was volatilized. With nickel only the volatilization was almost nothing, but the production of water-soluble nickel was small, being only 17.7 per cent at 550 deg. C. When both copper and nickel oxides were in the mixture, a maximum of 3.3 per cent of the nickel was converted into water-soluble and volatile compounds at 650 deg. C.

While these laboratory experiments do not prove the commercial feasibility of the proposed process, they suggest the possibility of effecting a separation and indicate the temperatures at which the roast should be conducted.

British Aniline Industry

In furtherance of the scheme for constituting a purely British undertaking for the purpose of manufacturing aniline dyes and allied products the government proposes to guarantee interest on a million and a half of debenture capital, subject to nomination of two members of the board by the government and to a veto which will insure exclusive and permanent British control. There is also a provision securing uniformity of prices to large and small consumers alike. To this outcome of the negotiations the energetic part played by Lord Moulton has contributed in no small degree.

Hydraulic Disruption in Mining

At a recent meeting of the Society of Engineers, Mr. James Tonge contributed a paper describing a "hydraulic mining cartridge," which, it is claimed, may be very advantageously substituted for blasting in mines of all descriptions, for excavations in rocks, breaking up concrete beds, and similar purposes. The instrument consists of a strong steel cylinder with lateral telescopic rams to give a long thrust. It is made in three sizes varying from 2½ to 4 inches in diameter, with eight rams in the smallest size, six in the intermediate, and five in the largest, and is worked at pressures of from three to five tons per square inch.

The general procedure in working wall coal is to drill a series of holes in the seam, from 6 ft. to 10 ft. apart and 3 ft. to 5 ft. deep, near and parallel to the root, and pump off the holes in succession from the free face of the seam. In headings the coal is undercut and sheared vertically in the middle, when one hole on each side of the shear, close to the fast side, will suffice. One man using one machine can pump 30 to 40 holes per 8-hour shift, and the machine will last, with repairs, from three to four years. A colliery in which over 1000 blasting charges were fired every week has adopted the hydraulic apparatus and entirely discarded explosives. In one 3-ft. seam with four machines in daily use, some 28,500 hydraulic thrusts were made in a year and gave an estimated output of 92,626 tons, about 3¼ tons for each thrust. In another case five machines are getting 450 tons per day with 75 per cent large coal and 25 per cent small as against 65 per cent large when explosives were used. Taking the price of large coal at 13s. and of small at 7s. the increase in value due to the five machines works out at £14 5s. per day, without counting the extra 6d. per ton the coal brought down with the machines commands on account of its superior hardness and freedom from dust.

The paper also gives particulars with regard to excavating rock and removing concrete beds which indicate that the hydraulic cartridge works quite as efficiently for these purposes as in coal mining.

Market Prices

November, 1914

	£	s.	d.
Aluminium ingots, ton lots	88	0	0
Alum, lump, loose, per ton	5	10	0
Antimony, black sulphide, powder, ton	28	10	0
Borax, British crystal, ton	18	10	0
Copper sulphate, ton	20	10	0
Caustic soda, 70 per cent., ton	10	2	6
Copper ore, 10 to 25 per cent., unit	..	..	..
Ebonite rod, lb	..	3	0
Hydrochloric acid, cwt	..	4	6
India rubber, para, fine, lb	..	2	8½
Mica, in original cases, medium	3/— to	..	5 0
Petroleum, Russian spot, gal	..	..	8¾
Quicksilver, Spanish, bottle	11	5	0
Sal-ammoniac, cwt	2	2	0
Sulphate of ammonia, ton	10	17	6
Shellac, cwt	2	15	0
Platinum, oz., nominal	9	5	0
Tin ore, 70 per cent., ton	..	..	..

Lead opened £18.10.0, was £18.15.0 on the 10th, and remained steady for the ensuing week, then rising to £19.10.0 on the 23d, £19.15.0 on the 24th, at which price it remained to close.

Hematite has been steady at 62/—.

Scotch Pig opened 55/4½ and rose from the 17th, reaching 56/10½ on the 23d and 57/4½ on the 25th.

Cleveland opened 49/— and was stronger after the 16th, rising fairly steadily from 49/4½ on that date to 51/6 on the 24th, but only 51/3 on the 25th. It improved toward the end of the month.

After the 16th the metal exchanged reopened for a short time each morning.

Copper at the end of October was about £55. In the earlier part of the month it ran easier, in anticipation of the settlement, being £50.10.0 on the 10th and about £52 on the 13th. By the 17th it had reached £53 and was £55.5.0 on the 23d, was rather easier on the 26th at £55 and closed (settlement price) £54.5.0.

Tin opened about £133 and was £139 on the 10th, re-

maining about this price to the 17th, when it was £138.10.0. By the 23d it was £139.15.0, £140 on the 24th, and £142 on the 25th. On the 26th it had reached £142.5.0 and closed £142.10.0 (settlement).

A New Continuous Filter

There has recently been installed at the Concentrating Mill of the Pennsylvania Steel Company at Lebanon, Pennsylvania, a continuous filter with several interesting and novel features which should insure for it wide application in many industrial operations. While rotary vacuum filters of various types have been on the market for years, there appears to have been little departure, aside from the mechanical design, in the filtering medium proper, and too little attention has apparently been given to the maintenance of the filter in the most efficient condition.

In principle, this new filter is virtually a wheel with shaft, hub, spokes and rim, rotating one-half submerged in the pulp to be filtered and operated by a vacuum. The hub carries a valve, the integral parts of which register with the port holes in the hub, said port holes communicating with the compartments formed by the radial spokes of the wheel.

The wheel is constructed entirely of cast iron and for convenience, the compartments are cast two to a segment, there being eight segments, or sixteen compartments, each being isolated from the other, communication being only through the port holes in the hub to the valve.

Between the radial spokes, so called, a web, which is cast in each segment, supports the filtering medium proper, this covering both faces of the wheel.

The segments are not truly symmetrical, but radiate from the hub at such an angle as to bring the peripheral end and the hub end to very nearly a horizontal position, three or four inches above a horizontal center line of the wheel.

This is done because the cake discharges at this point and because, by such an arrangement, the entire compartment is immersed in the pulp by the time the hub end is and no vacuum is thereby lost by having a bare plate exposed to the atmosphere. As the wheel rotates, the effect is that the rim end of the segment travels ahead of the hub end.

The wheel may also be built of other material than cast iron, should the occasion require.

Construction of this kind permits of a large filtering area in a comparatively small space, the total thickness of the complete wheel being but eight inches and with a wheel 10 feet in diameter, there is an available filtering area of 150 square feet. One or two wheels may be operated in the same tank, saving thereby considerable floor space and requiring a maximum head room of 11 feet.

The filtering medium proper is "filtros," a comparatively new porous, mineral medium which has been prepared in special segmental shapes for this device and which shapes are bolted on to the faces of the wheel through a center hole in each shape, the retaining washers being countersunk so that both faces present smooth, rigid, permanent and practically indestructible surfaces.

The seams between the segmental shapes, which are very narrow and hardly noticeable in operation, as well as the seams between the filtros and the cast iron portions, are filled with a suitable cement, which makes the confined areas proof against leaks and avoids some of the annoying features, so common to numerous filtering devices.

The advantages of such a porous medium over the usual canvas or other fibrous covers are obvious, as with ordinary care, it should last as long as the iron work itself. No frequent replacement or renewals with the time losses incident thereto, no muddy filtrate from a punctured canvas, no tears or breakage from excessive pressures as numerous tests have shown the material capable of sustaining pressures of 100 pounds per square inch, no taking down for scrubbing or cleaning, as filtros may be scrubbed with wire brushes or given an acid bath, if necessary, in place; the cast iron, of course, preventing the excessive use of strong mineral acids.

Furthermore, filtros can be supplied in such grades of porosity as will make the device applicable to the finest slimes or the coarser concentrates or fibrous pulp, giving in all cases where the pulp permits of proper treatment, an absolutely clear filtrate which requires no further clarification. With the appropriate grade of filtros selected, there is but little tendency for clogging of the porous medium and as noted later, the plates covering each compartment are subjected to a back pressure at a certain point in each revolution of the wheel.

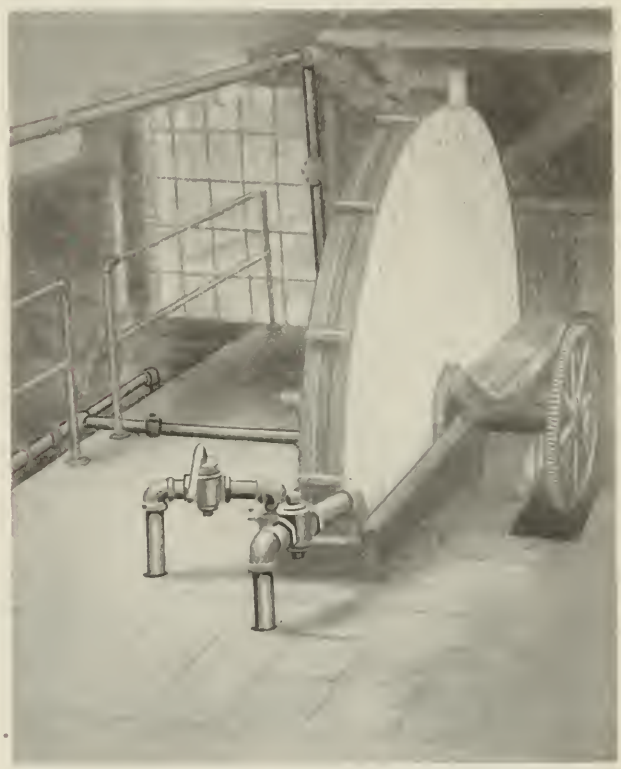


FIG. 1—CONTINUOUS FILTER

For a general cleaning up, a by-pass from the compressed air to the vacuum line permits the entire interior in the wheel and the filtros plates covering it to be thoroughly flushed with air or water. This can be accomplished in ten minutes' time by simply manipulating a few valves, and, depending upon the nature of the pulp being filtered, cleaning should be required only at infrequent intervals.

As stated, the wheel is vacuum operated, the full lower half only being constantly in the pulp. This is made possible by inserting packing collars in the walls of the tank, so that the hub and shaft are partly below the tank top, the said walls being carried to such a hight that there is at least one inch leeway when the wheel is just half submerged.

An over-flow is located at this point on one end of the tank, so that it is impossible to overflow the tank proper.

An outlet is also provided in the tank bottom for discharging the pulp remaining therein should a shut down be necessary, such amount always being small as but about two inches clearance is allowed all around for the wheel.

The wheel so nearly fills the tank that a comparatively small amount of pulp is in it at any one time and the tendency for the pulp to settle and retard the rotation of the wheel or to filter unevenly is thus avoided. Furthermore, the lugs on the rim of the wheel act as rakes for constantly stirring up the pulp and should the occasion require, as may be the case with a very heavy sediment, additional rakes extending both radially and lengthwise, can be attached to said lugs so that settlement of the pulp is impossible, as the sediment would be raked up for the full width of the tank sixteen times for each revolution of the wheel.

Additional agitating devices, which are required in many forms of continuous filters, are thus eliminated.

In the present illustration, the tank does not conform to the circumference of the wheel, though if desirable, it could be made semi-circular.

A door is also located on one side of the tank near the bottom, which is merely for use in emergencies, as when a tool or something of the kind may have been dropped in the tank.

The pulp is fed to the filter tank in the present in-

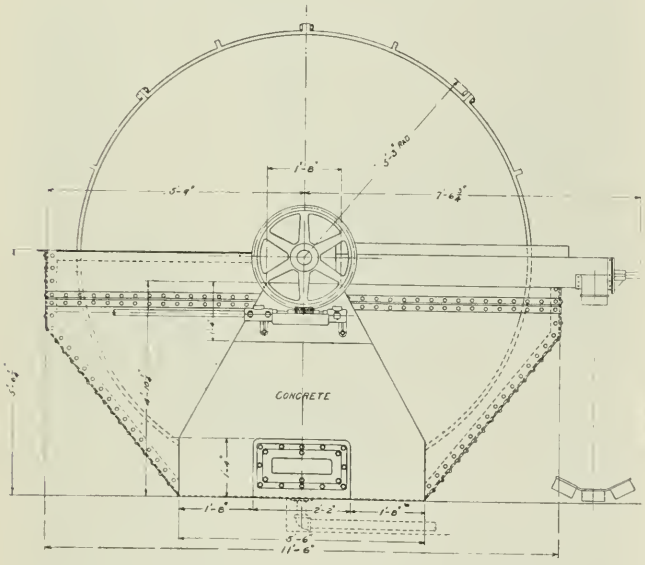


FIG. 2—SECTION OF CONTINUOUS FILTER

stance by two three-inch lines directly from the thickeners, though in some installations, an intermediate storage tank with constant level float valve may be desirable. The rate of filtration is so uniform, however, that no difficulty has been experienced in regulating the direct feed line.

The rate of revolution can be varied for most efficient results, these being dependent upon several factors. In general, it has been found that one revolution in three minutes is most desirable, this, with ordinary pulp, producing a cake of such thickness that it is easily discharged from the wheel and also lends itself to easy washing.

All else being equal, the faster the wheel revolution, the greater the tonnage capacity, though not necessarily the most effective results. For example, at the higher speeds, the cake contains more moisture and with the thinner pulps, the cake produced is not so easily handled.

The following brief table, showing some results on a lime sludge, will make these effects clear. The temperature of the pulp was in all cases, 50 F. (which is too low for best results, there being at least 50 per cent increased capacity at 100 F.), the proportion of solids was 36 per cent, liquid 64 per cent and the vacuum 22 inches.

One Revolution of Wheel In	Thickness of Cake	Moisture in Cake	Tons per Hour: Dry Matter	Tons per Hour: Wet Cake
4 min.	About 1″	37%	3.84	6.03
3 min.	About ¾″	39%	4.58	7.56
2 min.	About ½″	40%	5.03	8.44
1 min.	About ¼″	40.5%	5.48	9.28
0.5 min.	About ⅛″	41%	6.30	10.75

As a good illustration of the temperature effects, the following table applying to the same pulp may be cited, all at one revolution of the wheel in three minutes and at 22 inch vacuum.

Temperature, Deg. F.	Moisture in Cake	Tons per Hour: Dry Matter	Tons per Hour: Wet Cake
50	39%	4.58	7.56
61	39%	5.16	8.51
67	39%	6.05	9.99
81	39%	6.64	10.96

from which a marked increase in capacity is noted at the higher temperatures.

But to return to the operation of the wheel. As stated, each of the sixteen compartments communicates independently to the valve, the latter being made for either a right or left hand rotation and having on its outer face, near the bottom, a connection for the main vacuum line. As arranged in the present case, where no washing of the cake is required, fourteen of the sixteen compartments are constantly in communication with this vacuum line, eight of them being submerged in the pulp in forming the cake as they move slowly therethrough and six of them being exposed to the air, the vacuum withdrawing the moisture as far as possible during this exposure.

Where washing of the cake is required and the washings and main filtrate must be separated, an additional vacuum line is attached to the outer face of the valve, so that the last mentioned six segments are independently connected.

Of the two remaining compartments, the one adjacent to these under vacuum, registers with a vent hole in the valve and releases such vacuum as may be retained therein.

This venting arrangement has proved a very economical factor in the operation of the filter as the vacuum is not neutralized by compressed air—which would be the case in the absence of any vent—the compartments in passing the vent hole simply coming under atmospheric pressure, and the sudden shock from vacuum to pressure is thus avoided.

The remaining compartment registers with a compressed-air line attached to a suitable location in the valve and with a pressure of two or three pounds per square inch, the cake is blown off the filter plates clean.

Thus the sequence of operations, as the wheel slowly revolves.

With a three-minute revolution, the wheel is forming the cake for ninety seconds, sucking out the retained moisture for 67½ seconds, releasing the vacuum 11¼ seconds and blowing off the cake for 11¼ seconds.

But very low pressures are required to dislodge the cake owing to its partial release by the vent hole and in the case of certain materials, it may even drop of its own weight.

In any event, just sufficient water to lubricate the face of the filtros plates and allow the cake to slip off cleanly, needs to be blown back. There is but little tendency for even a very slimy cake to adhere to the filtros plates, as the surfaces are smooth and extremely rigid.

Furthermore, what little water is blown back, runs directly down the face of the wheel into the tank as

the scrapers or aprons which catch the cake do not touch the face of the wheel by one-eighth inch or so. This slight back flushing of each compartment at every revolution of the wheel keeps the filtros plates in the highest state of efficiency and as each compartment advances for submergence in the pulp, a clean bare surface is each time presented for a new cake. This feature in connection with the previous remarks respecting the general clean-up maintains the apparatus in a high state of efficiency.

The aprons or scrapers referred to are made adjustable and are attached to and extend over the top of half of the tank on each side of the wheel and conduct the cake into worm-conveyor troughs, similarly located, from which it may be conveyed to cars or stack.

These worm conveyors are driven by chain and sprocket, rotating in the same plane as the shaft which drives the wheel. The shaft of the latter carries a worm gear on the end opposite from that of the valve.

In the present installation, it has not been convenient to determine the actual horsepower required to run the wheel, but it is estimated not to exceed 1 hp, as the wheel is so nearly balanced.

In a total rotating weight of about 9000 lb., only 8 to 11 lb. are lost by removal of the cake from the discharging segment, which, with the gradual loss of moisture from the exposed segments of the wheel, represents approximately the driving power needed.

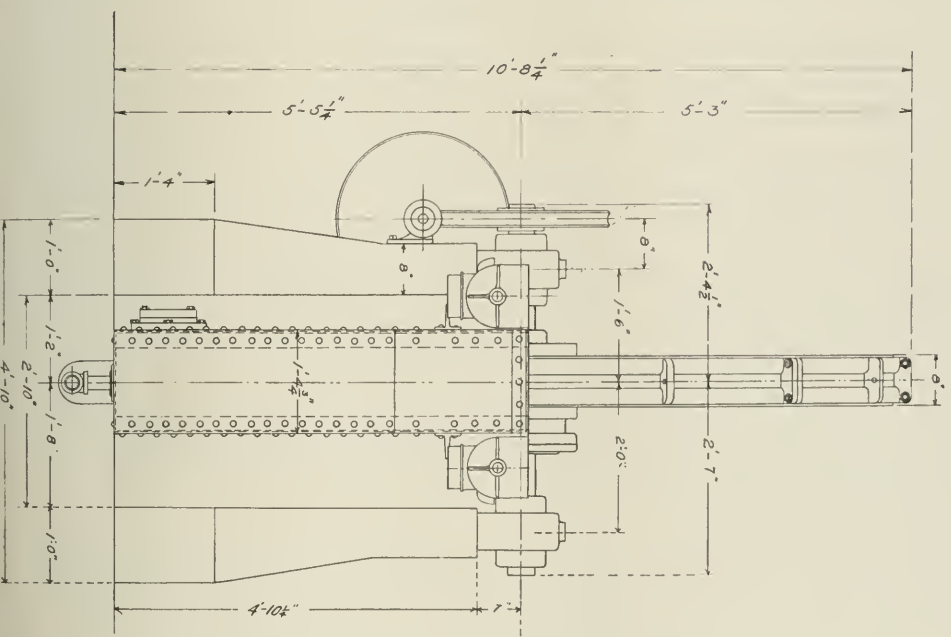


FIG. 3—SECTION OF CONTINUOUS FILTER

The worm conveyors probably require as much power as the wheel proper.

Vacuum pump power is not here considered, as this would be required with any vacuum filter.

Aside from the wear and tear on mechanical parts, the up-keep of this filter is apparently nil, as the permanency of the filtering medium removes the largest item in this respect.

The capacity of the wheel in the present instance has been difficult to estimate accurately, as the density of the feed pulp is constantly varying. The capacity is, furthermore, dependent upon so many factors that it can only be stated that from 45 to 60 tons of dry solids are being handled each twenty-four hours.

The cake was approximately ¼ in. thick at 15-in. vacuum and carried about 27 per cent. moisture; about ⅜ in. thick at 24-in. vacuum and carried 23 per cent. moisture.

In justice to the wheel, it should also be stated that the present proposition is not an ideal one, the mill tailings being filtered, showing on screen analysis but 2.5 per cent. on 100 mesh and 72 per cent. through 200 mesh. Water in contact with them requires a slight acid reaction and the finer portions are of a clayey nature and in a colloidal condition. As an illustration of what may be done under more favorable conditions, some experiments with this pulp showed that by adding one-quarter of 1 per cent. of lime, an increased capacity of 18 to 20 per cent. was obtained on the wheel. As the problem was mainly the disposition of a waste material, however, the lime treatment has not been applied yet.

The present filter wheel is but one of a battery of several to be installed at this plant and is the invention of Col. W. W. Robacher of Rochester, N. Y. The United States and foreign patents are controlled by The General Filtration Company, Inc., of Rochester, N. Y., who are making the present installation.

An Examination of Fire-Bricks

"An Examination of Fire-Bricks and Some Other Technical Refractory Materials" is the subject of a report by **W. Hamilton Patterson** in the (British) Iron and Steel Institute Carnegie Scholarship Memoirs, Vol. 6, page 231, 1914. The author considers only those refractory materials which are cheap and have therefore more general application. The ordinary fire-clays are the raw materials from which the majority of these are obtained with or without the addition of other substances, such as ganister or bauxite.

Fire-bricks made from these have wide application and are selected to suit various conditions. Three large industries may be instanced—the production of iron and steel, the manufacture of glass, and the cement industry, with special reference to the lining of rotary kilns for the making of Portland cement.

In each of these industries various conditions obtain, and the refractory material is chosen to comply with them as far as possible.

The author discusses the valuation of fire-brick in three respects:—chemical analysis, specific gravity and limit of refractoriness. Only bricks and materials which may be considered highly refractory, that is, with a melting point of 1600 deg. C. and upward, are considered.

The importance of correct ultimate analyses of clays and fire-bricks made from clays is emphasized. The author proceeded as follows: "The sample is prepared by successive grindings and quarterings, and finally passing through a sieve of at least 90 mesh. It is then, in the case of a fire-brick, dried at about 150 deg. C. to remove any accidental moisture.

"The loss of ignition on 1 gram is determined by heating over the blowpipe flame.

"Half a gram of the sample is fused in a platinum crucible with at least 2.5 grams of fusion mixture ($K_2CO_3 + Na_2CO_3$), the heating being carried out care-

fully over a small Bunsen flame and finally over a full flame.

"The melt is extracted with water and hydrochloric acid, and the whole evaporated to dryness on a water bath. It is moistened with concentrated hydrochloric acid and again evaporated to dryness. Finally, care is taken to evaporate a third time to complete dryness. This can be hastened by placing it in the air oven, but as it is not advisable to ignite the residue at a temperature of more than 111 deg. C. to 120 deg. C., the water bath alone is perhaps preferable.

"*Silica.*—The whole is taken up with hot dilute hydrochloric acid and the silica filtered off and digested with some more dilute hydrochloric acid, and finally washed with hot water until the washings are free from chlorine. This gives nearly the correct amount of silica as slight errors compensate, but its purity may be tested in the usual way by treatment with hydrofluoric acid plus a few drops of concentrated sulphuric acid.

"*Alumina, Ferric Oxide, Titanium Oxide, etc.*—These may be determined together by double precipitation with ammonia, or determined together in one portion of the filtrate, another equal portion of the solution being reduced with hydrogen sulphide, the latter expelled by boiling and passing through carbon dioxide, and finally titrating the iron with N/50 permanganate solution.

"Finally, in a part of the filtrate, usually half the amount taken for either of the above, the titanium is estimated by the well-known color reaction of Weller, by adding hydrogen peroxide, freshly made from sodium peroxide.

"If the iron and titanium are each separately determined from the alumina the precipitate is dissolved for the second time in dilute sulphuric acid instead of hydrochloric acid.

"Calcium oxide, magnesia, and the alkalies are determined by the usual gravimetric methods, the Lawrence Smith method being adopted for the alkalies.

"Titanium oxide is a widely occurring substance and yet it is remarkable that if one looks up the analysis of silicates and clays in various text-books different statements are given as to its estimation. Thus in Lunge, 'Technical Methods of Chemical Analysis,' it is distinctly stated that the titanium comes down with the silica. On the other hand, Treadwell, another authority, in his well-known book on analysis, makes no mention of titanium coming down with the silica at all, but says that it is precipitated by ammonia in the iron and alumina group. The latter statement is the more correct. The following results were obtained in the case of two fire-bricks:

"1. Total weight of silica residue obtained = 0.3643 gram, 2.06 milligrams were left after treating with hydrofluoric and sulphuric acids.

"Of this 0.0005 gram was found to be titanic oxide, which corresponds to 0.10 per cent of titanium oxide in the total fire-brick. But in the same analysis there was also found after separation of the silica as above, with the iron and alumina, titanic oxide equivalent to 1.00 per cent of the total brick.

"2. In this case 0.17 per cent titanium oxide was found with the silica and 0.76 per cent with the iron and alumina. It seems probable that the amount of titanium oxide brought down with the silica increases according to the temperature to which the silica is subjected after evaporation of the hydrochloric acid. The hydrochloric acid used to dissolve the iron and alumina, etc., from the silica after final evaporation to dryness also ought not to be too diluted."

The limit of refractoriness was determined in an electric tube furnace, using a carbon tube with a hydrogen atmosphere.

The test-pieces of the brick, which were small, pointed pieces, were placed in holes in a small graphite boat, as much pointed end projected up as possible. The softening point was recorded when the ends began to bend slightly or round at the top, but as a rule this was not measured, being rather uncertain. The melting point was taken when they collapsed. This, as a general rule, was perfectly definite, and the temperature at which it occurred could be easily defined.

The temperature was measured with a Wanner optical pyrometer. Table I is a list of some of the melting points obtained.

Analyses of some of the samples, the melting points of which are recorded in Table I, are given in Table II.

Table I.—Melting Point

No.	Description	Melting Point, Deg. C.
1	Fire-bricks, ordinary	1620
2	" "	1610
3	" "	1630
4	" "	1610
5	" "	1610
6	" "	1660
7	" "	1680
8	" "	1865
9	" "	1735
10	" "	1860
11	" "	1735
12	" "	1735
13	Dinas silica brick	1680
14	Magnesite brick	1860
15	Special block	More than 1915
16	Bauxite brick	1770
17	Chrome iron ores	1730
18	" " "	1725
19	" " "	1630
20	" " "	1545
21	" " "	1630
22	Bone ash cupel	1865

Table II.—Ultimate Analysis

No.	Specific Gravity	Silica, per cent	Alumina, per cent	Ferric Oxide, per cent	Titanium Oxide, per cent	Total $Al_2O_3+Fe_2O_3+TiO_2$ per cent	Calcium Oxide, per cent	Magnesia, per cent	Alkalies, per cent	Loss on Ignition, per cent
9	2 176	57.0	.	.	. . .	39 6	0.60	0.45	. . . .	. . . .
10	2 139	66 0	.	.	. . .	31.5	0.44	0.52	. . . .	0.05
11	2 220	73.2	18 3	6 6	0.49	25 3	0.04	Trace	0.5	0.22
12	2 185	74 4	.	.	. .	23 3	0.88	0.45	. . . .	0.31
13	2 162	96.6	.	.	. .	0 35	1.50	0.06	. .	. . . .
16	2 38)	57 1	36 0	4 6	1.44	42.0	0.34	0.06	. . . .	. . . .

Fire-Brick for Lining Rotary Kilns.—The question of choosing suitable refractory material for the lining of the clinkering zone of rotary kilns for the production of Portland cement is of interest and importance. As the brick will have to contend against highly basic substances it might be naturally supposed that a basic brick will best fulfil the conditions required.

An examination of a brick which gave very satisfactory results in practice, however, led to the following results:—

	Deg. C.
Melting point	1735
Density	2.217

Ultimate anyalysis—

	Per Cent
Silica	73.2
Alumina	18.3
Ferric oxide	6.5
Titanium oxide	0.4
Calcium oxide	0.4
Magnesia	trace
Alkalies	0.50
Loss on ignition	0.22

The explanation of the success of such a brick for the purpose is given from the fact that it fuses on the sur-

face, and forms with a cement clinker a protective coating which prevents further attack. The question of protective coatings is thus important in judging the practical refractoriness of fire-bricks.

The investigation was carried out in the Muspratt Laboratory of Liverpool University.

A Diatom Heat-Insulating Brick

In the wall construction of furnaces, kilns, boilers, etc., two entirely different problems must be distinguished. One is to provide a refractory lining which will stand the high temperature, the chemical action of the charge, etc., without being destroyed. The other problem is to provide heat insulation, that is, to provide a lining which lets as little heat as possible pass from the inside to the outside. These are two entirely different problems and cannot be solved in general by the same material. In furnace design and construction it is usually very much better to keep the two problems separate and solve each separately, that is, to provide a composite wall consisting of a lining of firebrick or other highly refractory material next to the charge, this backed up by a highly heat-insulating brick, and this again backed up on the outside by ordinary brick.

For the purpose of heat insulation, kieselguhr or infusorial earth has been known for years to be a most excellent material (see, for instance, the extensive article on kieselguhr in our Vol. XII, page 109). But to get kieselguhr in brick form has been a problem in itself and a rather difficult one which has only been solved in recent years. For this reason the following notes on the "nonpareil insulating brick" of the Armstrong Cork Company of Pittsburgh, Pa., should be interesting.

Nonpareil insulating brick is made as follows: Bricks are formed of a mixture of kieselguhr, a small amount of clay, and finely ground cork. The mixture while wet is molded into brick measuring 9 x 4 x $2^1/_2$ inches, which are dried and then fired. The cork is first carbonized and then gradually burns out completely. In this way, the brick is subjected to uniform heat through its entire mass. The burning out of the cork leaves the brick porous in texture and a light terra cotta in color. The cubical contents of a single brick are 90 cubic inches. The weight averages $1^1/_2$ pounds. A cubic foot of the material, therefore, weighs approximately 29 pounds.

As to insulating efficiency, the heat conductivity of nonpareil insulating brick is approximately 12 B.t.u. per square foot per degree difference in temperature per one-inch thickness per twenty-four hours. The transmission through fire brick or ordinary building brick will average 120 B.t.u. Thus nonpareil insulating brick transmit one-tenth of the heat transmitted by ordinary building brick; or, in other words, the insulating efficiency of a single course of nonpareil brick 4 inches thick is equivalent to that of 40 inches of ordinary brick.

The high insulating value is due to the structure of the diatoms making up the kieselguhr, as it is composed of the skeletons or shells of almost pure silica, hollow and filled with air, and it is due to the large volume of air confined in minute particles that diatomaceous earth owes its pre-eminence as a natural heat-insulating material.

Being composed so largely of diatomaceous earth which, as just explained, is practically pure silica, nonpareil brick will withstand relatively high temperatures —much higher in fact than any other form of insulation designed for similar purposes. The fusing point is about 1600 degrees F.

Further, nonpareil insulating brick combine insulating efficiency with a sufficient degree of strength to enable their being used as a structural material. While weighing but $1^1/_2$ pounds each, they will stand a crushing load of 140 pounds to the square inch. They are just as easy to lay as ordinary brick, and in fact, are more readily shaped and cut, where fitting becomes necessary.

Another marked advantage of nonpareil insulating brick as compared with other insulating materials is its resistance to moisture. The brick may be soaked in water or subjected to steam for an indefinite period of time, and after being permitted to dry out will be found to be as strong and efficient as they were before such treatment. There need be no hesitancy, therefore, in employing them in places where they may be subjected periodically to water or dampness.

In installing nonpareil insulating brick the importance of securing continuous insulation—without breaks —should be kept constantly in mind. The brick should be laid in a special insulating cement, which is composed of practically the same substances as the brick themselves and has substantially the same insulating value. Thus nonpareil insulating brick laid with this special cement, provide a solid, unbroken wall of insulation.

As mentioned before, nonpareil insulating brick may be laid between the inside fire brick and the outside common brick, or they can be placed outside the common brick and the exposed surface finished off with a coat of cement plaster. In every case, an inner lining of fire brick must be used, for nonpareil brick are not a refractory material and will not withstand the abrasion to which fire brick are ordinarily subjected.

In recent years the Armstrong Cork Company has evolved a high-pressure covering for steam pipes which is distinctive because it is the only covering made of diatomaceous earth and asbestos. It contains no cork whatever. It is particularly well suited for the insulation of superheated steam surfaces. Moreover, it will bear repeated wetting and drying without injury and for this reason is an ideal form of covering for underground steam lines.

Further information on the use of the diatom insulating brick may be found in the bulletins of the manufacturers, the Armstrong Cork Company of Pittsburgh, Pa., entitled "Nonpareil Insulating Brick," "Comfort and Economy in the Bakery" (heat insulations of bake ovens), "Nonpareil Insulating Brick in Glass Houses," "Permanent Fortifications" (the use of insulating brick in refrigerating plants), and "Saving Fuel" (use of insulating brick for boiler settings).

Paint Remover Patent Decision

The suit of the Chadeloid Chemical Company against the Wilson Remover Company and John MacNaul Wilson for alleged infringement of the Carleton Ellis paint remover patent 714,880 of December 21, 1902, was determined last month in favor of the complainant by Judge Hand in the United States District Court, Southern District of New York. The decree grants the Chadeloid Chemical Company a permanent injunction restraining the defendants from making, using or selling the compositions in issue without license from the complainant and provides for the usual accounting of damages, alleged to have been sustained by reason of the infringement.

Judge Hand, in his decision, says that no successful paint remover had appeared when Ellis set to work. Immediately, his invention went into great use and has substantially controlled the field. All the elements exist which justify one in calling Ellis's patent a pioneer patent.

The decision discusses at some length the contention of the defendant that the "suitable solution" of the patent was not practicable. In final answer to this "it is enough to say that a paste made exactly after the directions of that example was sold under the name

of phenoid and had a successful, though limited, market. However, even if the 'suitable solution' had been very inferior it would have been immaterial if the patent had shown the road to success, as it certainly did. The commercial composition was clearly disclosed, because the patentee gives a large range of equivalents, both in solvents, waxes and alcohols."

"Having determined that the patent is broadly valid because of its basic character, the question arises of infringement. It is quite true that, put in one form, it is accurate to say that Ellis merely omitted one element of the prior art, phenol, but that is a very meagre measure for the real invention. The fact was that the art had relied upon phenol (which no one wanted), because it was at once a potent solver and a non-evaporant. . . ."

"If then it be asked at what point the percentage of phenol avoids infringement the answer is not hard; substantially at that point where the prior art supposed it was necessary, as shown by the lowest percentage it had reached. Since Ellis emancipated the art from the necessity, his monoply should extend to the degree of that emancipation."

Obituary

Charles Martin Hall, whose name will forever be remembered in connection with the foundation of the American aluminium industry, died in Daytona, Fla., on December 27, 1914. At the time of his death he was vice-president of the Aluminium Company of America, but for the last few years he had been in poor health and had been forced to retire to a degree from his formerly very active engineering and business life. As a

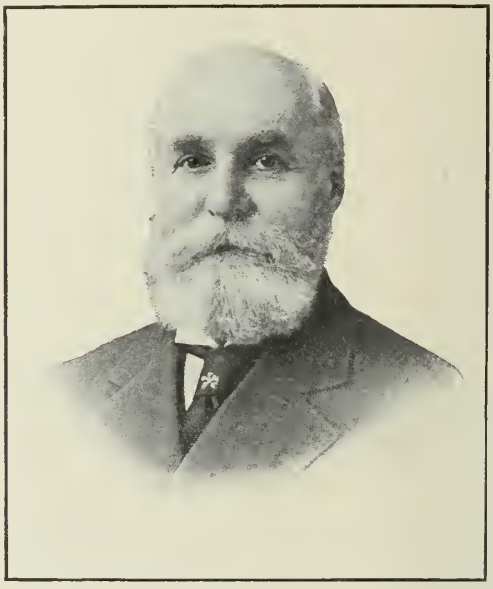
THE LATE CHARLES M. HALL

full biographical sketch of Mr. Hall was given in our Vol. I, page 10, only the principal dates of his life will be stated here.

Charles M. Hall was born at Thompson, Geauga County, Ohio, on December 6, 1863. His father was a congregational minister, and moving to Oberlin in 1873, young Hall attended the public schools there and later Oberlin College. There he had one term of chemical study with Professor Jewett and was so captivated with the subject that for nearly a year thereafter he experimented in the Oberlin laboratory, with the special object of finding an electric method of commercially producing aluminium. His experiments were first crowned with success on February 23, 1886, his chief invention being the electrolyte now universally used. Heroult had made simultaneously and independently the same invention in France. To carry out Hall's process, the Pittsburgh Reduction Company was formed in 1888 and began turning out aluminium commercially in November, 1888. The further development of the aluminium industry is history. When Hall started, aluminium was worth about $25 a pound. Hall's later inventions all had some relation to the aluminium industry. He improved especially methods of purifying alumina, baking carbon electrodes, etc. He received the honorary degree of LL.D., from Oberlin College in 1910, and the following year he was awarded the Perkin gold medal from the allied chemical societies of this country. Mr. Hall made his home at Niagara Falls. He was a bachelor.

* * *

Theodore Armstrong, president of the Pennsylvania Salt Manufacturing Company, died on January 5, at his



THE LATE THEODORE ARMSTRONG

residence in Philadelphia, aged 71 years. He had been in failing health for some time. He was born in New York and served in the army during the Civil War. After the close of the war he obtained a position to audit the accounts of internal revenue collectors in Philadelphia and neighborhood. Soon after he became connected with the Pennsylvania Salt Manufacturing Company, and later was appointed chief accountant of the company's works at Natrona, Pa. Seven years later he was made chief auditor at the Philadelphia offices of the company and later became successively secretary, treasurer, vice-president and president. He was chosen president in 1888, and had since held that office. Under him, the management of the company was practically reorganized and many improvements made in its operation and general business, constituting it one of the foremost concerns of its class in the country. Mr. Armstrong was also president of the Wedge Mechanical Furnace Company and a director in several other companies. He had been, for several months, too sick to attend to business and Joseph Moore, Jr., was chosen president pro tempore to perform his duties. He was a member of the Society of Chemical Industry, the American Chemical Society, the National Geographical Society and of many clubs and societies in Philadelphia, where he leaves many devoted personal friends.

Concrete Pumps

Reinforced concrete pumps are the subject of quite an interesting new invention of Mr. Henry De Huff of Philadelphia. They are furnished built complete in place by the D'Olier Centrifugal Pump & Machine Company of Philadelphia, or, if desired, this company furnishes the necessary iron parts and reinforcing bars with complete drawings for the concrete work. This invention is of especial interest in connection with very large capacity pumping projects such as dry docks, drainage and irrigation work. The concrete construction renders practicable the use of pumps of larger capacity that have heretofore been practicable, so that pumps having a discharge connection 10 feet in diameter or larger can be built. The pump is provided with stationary rings with which the pump impeller forms a close clearance and these rings serve as anchorage for the reinforcing bars and a means of centering the concrete. We reserve a more detailed description for our next issue.

Personal

The Anaconda Copper Mining Co. has made some changes in its technical staff recently. Mr. **Frederick Laist** will be metallurgical manager for the plants at Great Falls and Anaconda, having supervision over construction and technical matters. He is succeeded as general superintendent of the Washoe plant by Mr. **L. V. Bender,** who has as assistant Mr. **H. S. Ware.** The business of the Great Falls and Anaconda plants will be in charge of Mr. C. W. **Goodale** and Mr. **E. P. Mathewson** as heretofore.

Mr. Albert Burch has resigned his position as general manager for the Goldfield Consolidated Mines Co., being succeeded by Mr. **J. W. Hutchinson.** The position of assistant general manager vacated by Mr. Hutchinson will be filled by Mr. **K. M. Simpson.**

Mr. **Noel Cunningham** is engaged in professional business in the southwest, with headquarters at Douglas, Ariz.

Mr. **A. E. Drucker** has gone to Colombia to build a cyanide mill for the Frontino & Bolivia Gold Mining Co.

Mr. N. V. Hansell, of Hamilton & Hansell, 50 Church Street, New York, sailed on Saturday, the 23rd inst., for Europe. He expects to visit England, Russia and the Scandinavian countries before returning to New York.

Mr. **G. J. Kapteyn** has gone to Colombia as superintendent of the cyanide mill of the Bar Principal Mining Co.

Mr. **O. M. Kuchs** has been promoted from assistant superintendent to superintendent of the Toledo smelter of the International Smelting & Refining Co.

Messrs. **John D. Ryan, Benjamin B. Thayer** and **C. K. Kelley** of the Amalgamated and the Anaconda copper companies were in Great Falls, Mont., on a trip of inspection of the smeltng and refining property and conference regarding its future.

Mr. **W. G. Swart** has accepted appointment as consulting engineer for the Hardinge Conical Mill Company, devoting only a part of his time to his new duties and retaining his connection with the American Zinc Ore Separating Company in Denver.

Mr. **C. C. Titus,** manager for the Northwest Metals Co., of Helena, Mont., has been spending several weeks in Denver.

Mr. **Charles S. Witherill** has gone to Chuquicamata, where he will act as general superintendent of the reduction plant of the Chile Exploration Co. He was formerly superintendent of the copper department of the Balbach Smelting & Refining Co. He will be assisted by Mr. **L. M. Green** in charge of leaching, with Mr. **M. R. Thompson** in charge of the electrolytic tank house and Mr. **Otto Koch** in charge of smelting and melting.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Electroplating (Concluded)

672,074, April 16, 1901, George D. Burton, of Boston, Mass.

Relates to an apparatus in which currents of electricity are used in connection with a saponaceous fluid for cleansing cloth, wool, cotton, yarns, or other articles; and it consists in applying to a tank containing a suitable detergent solution, electrical conductors for electrolyzing and heating the solution. The apparatus consists of a tank containing an inner adjustable compartment, having perforated walls, and within which are the articles to be cleaned. Adjacent the ends and bottom of the inner compartment are conductors, so proportioned that a part of the current flows through the conductor, thereby heating the solution, and the remaining part passes from one end conductor through the solution to the other end conductor. The current passing through the solution is said to act on the solution and the articles and cleanse and improve them. The solution may be water, or a weak solution of sal-soda, borax, concentrated lye, or other saponaceous or alkaline liquid.

678,383, July 16, 1901, Ferdinand Eppler, of Berlin, Germany.

Relates to a process of metal ornamentation, by undercutting grooves for inlaid work, and depositing metal in the undercut grooves. The grooves may be partly filled with strips of wire cloth, which effects an economy in metal deposited; and when the grooves are cut in nonconducting material, such as granite, etc., the strips of wire cloth serve as conductors. A number of ways are suggested for securing the conductor, and also to produce ornamental effects.

687,386, Nov. 26, 1901, Botho Schwerin, of Munich, Germany.

Relates to the extraction of sugar from saccharine matter, such as beet-root, sugar-cane, sorghum, and the like, by the electric current. The substance containing the sugar is disintegrated, or finely subdivided, and enclosed in a wet state between a porous diaphragm and a permeable electrode connected as cathode; the anode is placed within a compartment containing water, with a body of water between it and the diaphragm. Upon passing the current, acidic elements are transferred to the anode compartment, while water, alkaline components, and soluble albumen compounds, together with the sugar, pass through the permeable cathode. It is stated that the electric current does not "invert" the sugar. The sugar is separated from the liquor containing it, and from the other substances present, by known methods.

688,857, Dec. 17, 1901, Warren Johnson, of New Orleans, La.

Relates to correcting the weights of metal blanks for coins, etc. In practice, the blanks vary in weight, some are too heavy and others too light. The heavy blanks are placed in a holder and connected as anode, the lightweight blanks being connected as cathode, and both im-

mersed in a suitable electrolyte, the current removing the excess metal from the anode and depositing it upon the cathode; or the blanks may be connected up with ordinary anodes and cathodes to correct their weight.

691,803, Jan. 28, 1902, William F. Patton, of Toledo, Ohio.

Relates to making seamless hollow spheres for floats for steam or water traps. A hollow sphere of paraffin is first made by pouring melted paraffin in a sectional mold and rotating the mold to form the paraffin sphere. After cooling the paraffin sphere is removed, a connecting nipple attached, and the sphere coated with plumbago and "iron by hydrogen," after which it is immersed in a solution of copper sulphate to give it a chemical deposit of copper. It is then electroplated to the desired thickness, the electrodeposit making a firm joint with the connecting nipple. After electroplating the paraffin is melted and run out through the nipple.

694,658, March 4, 1902, Jules Meurant, of Liege, Belgium.

Relates to processes of electrodepositing metals, and to electrolytes in which "addition agents" are added. A variety of addition agents are mentioned, including carbohydrates, organic acids, gums, gelatine, etc. Specific examples are given for zinc, tin, nickel, copper, and silver. With zinc, it is stated that a steel tube, zinc plated, was crushed and then folded upon itself without the deposit stripping. The patent should be consulted for details.

703,857, July 1, 1902, Constantin Jean Tossizza, of Paris, France.

Relates to a process of electrodepositing metals, such as zinc, nickel, cobalt, and cadmium, from solutions containing sulfurous acid, which consists in electrolyzing a solution of zinc sulfate with copper anodes, requiring a minimum voltage of 1 1/10 volts, up to about 1 5/10 volts, with a current density of 40 amp per square meter. The solution containing copper sulfate, after charging with sulfurous acid, is now separately electrolyzed with insoluble anodes, requiring a minimum voltage of 31/100 volt, up to about 5/10 volt. The acid liquor obtained, sulfuric acid, is used to dissolve more ore. Taken together, the two operations permit the electrolysis of zinc at a voltage which is the sum of these two operations, a minimum of 1 4/10 volts, and with acceptable current densities, about 2 volts. See patent No. 710,346.

705,456, July 22, 1902, Duncan Sinclair, of Coalbrookdale, England.

Relates to producing an iridescent coating upon copper, bronze, or like surfaces. The article is first thoroughly cleaned, then connected as an anode and suspended in a solution made of 14 oz. of caustic soda, 10 oz. litharge and ½ gal. of water, boiled for one hour, and then diluted to a gallon. To the above solution is added a small proportion of copper-plating solution, which is made as follows: dissolve 1 lb. of potassium cyanide in 1 gal. water, suspend a weighed copper anode sheet therein and pass a current from the copper until the solution contains 3 oz. of copper to the gallon. A current is passed from the copper article to be made iridescent as anode in the above solution for a time and at a current density depending upon the graduation of color desired. When this is reached, it is taken out, thoroughly dried, and may be subjected to heat varying according to the effect desired, from 150 deg. Fahr. to 500 deg. Fahr. The heating intensifies the color of the iridescent coating which is said to consist of an oxide of lead containing copper.

710,346, Sept. 30, 1902, Constantin Jean Tossizza, of Paris, France.

Relates to electrodepositing copper from the sulfate solution resulting from the treatment of roasted copper ores with sulfuric acid. The sulfate solutions thus obtained contain besides copper, sulfate of iron, and other metals. During electrolysis, the voltage tends to rise, resulting in the depositing of other metals, and finally spongy iron. The present invention relates to electrolyzing such impure solutions with carbon anodes, and depolarizing the same with sulfurous acid, either as a gas or liquid, which may be passed into a hollow anode, or over the outer surface thereof. The sulfurous acid is oxidized to sulfuric acid, and reduces the voltage required to electrodeposit the copper, with working current densities, to 6/10 volt. The sulfurous acid is obtained by roasting sulfid ores. See patent No. 703,857.

713,277, Nov. 11, 1902, Anson G. Betts, of Lansingburg, N. Y.

Relates to electrodepositing and refining lead and its alloys. The electrolyte described in his prior patent, No. 679,824, dated Aug. 6. 1901, is used, to which is added a reducing agent, such as gelatin, pyrogallol, resorcinol, saligenin, ortho-amido-phenol, hydroquinone, and sulfurous acid. Of these gelatin is the cheapest and gives the best results. One part of gelatin is dissolved in hot water and added to 5000 parts of solution. A current density of 10 to 20 amp per square foot of cathode surface is used. A product is easily made with a specific gravity of 11.36, the same metal remelted and cast having the same density. With higher current densities the lead becomes harder and more brittle. A sample deposited with a current density of 40 amp per square foot showed a specific gravity of 11.276. The presence of the reducing agent serves to restrain crystallization of the deposit. Gelatin and pyrogallol give projections that are nodular on thick deposits. See patent No. 713,278.

713,278, Nov. 11, 1902, Anson Gardner Betts, of Lansingburg, N. Y.

Relates to electrodepositing and refining lead and its alloys, and claims the product produced by the process described in his co-pending application, which became patent No. 713,277.

716,306, Dec. 16, 1902, Otto Carl Strecker, of Cologne, Germany.

Relates to preparing printing plates by electrolytic etching. The plate properly prepared and coated with a resist is connected as an anode in an electrolyte, which for a zinc plate may be a 2½ per cent solution of fluoride of sodium, a current density 0.5 amp to 0.9 amp per square foot being used for from two to five minutes. The patent should be consulted for details.

Book Review

Laboratory Course in Electrochemistry. By **Oliver P. Watts**, of University of Wisconsin. 150 pages, 16 illustrations; price, $1. New York: McGraw-Hill Book Company, Inc.

This book contains in abridged form directions for 133 experiments illustrating elementary principles and some advanced principles of the electrolysis of solutions and of fused salts. Electric furnace operations and detailed electrochemical analysis are not considered.

The dominant idea of the book is to guide students into observing and understanding the real principles involved in electrolysis. Assuming, of course, that they have a competent and enthusiastic instructor, Dr. Watts' book is admirably suited to its purpose. It is clear, direct, stimulating to observation and thought, and puts more weight on principles than on details, on contriving with simple apparatus than on merely using expensive special apparatus. We heartily commend the book to all beginning work in the electrochemical laboratory.

Metallurgical and Chemical Engineering

A Consolidation of Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII | New York, March, 1915 | No. 3

PUBLISHED MONTHLY BY THE

McGraw Publishing Company, Inc.

James H. McGraw, President.
A. E. Clifford, Secretary.
John T. DeMott, Treasurer.
239 West 39th Street, New York.

Telephone Call, 4700 Bryant.
Cable Address, Metchem, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Colo.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; for all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

New York, March, 1915

Editorial:
Copper and the Flotation Process 133
The War and American Iron Trade 134
Taking Care of the Human Element 134
The Pyrophoric Alloy Decision 135
Readers' Views and Comments:
The Action of Fluorspar on Basic Open-Hearth Slag. By H. O. Hofman 136
Examination of Fire Bricks. By J. S. Beckett 136
Fused Silica Dishes for the Concentration of Sulphuric Acid. By Albert E. Marshall 136
Quantitative Blowpipe Analysis. By Joseph W. Richards 137
Limitations of the Electric Furnace in the Manufacture of Steel Castings. By E. F. Lake 137
Tube-Mill Tonnage Calculation. By Noel Cunningham. 138
Western Metallurgical Field 138
Present Tendencies in Copper Metallurgy. By E. P. Mathewson 141
Magnesium 141
Concentration by Crushing and Screening at the Vindicator Consolidated Mill 142
The Radium Situation. By Warren F. Bleecker 143
Court of Appeals Decision in the Pyrophoric Alloy Suit 145
Non-Ferrous Metal Market 146
Mellon Institute of Industrial Research 146
A Classification of High-Temperature Physical Problems. By Edwin F. Northrup 147
Leaching a Zinc-Lime Ore with Acids. By A. E. Gartside and O. C. Ralston 151
The Determination of Manganese in Ferrovanadium. By William W. Clark 155
Purification of Boiler Feed Water. By Everard Brown 156
Filling the Blast Furnace. By J. E. Johnson, Jr. 161
The Hardening of Metals Before the Faraday Society 173
Annual Meeting of the American Institute of Mining Engineers 177
Recent Chemical and Metallurgical Patents 185
Synopsis of Recent Chemical and Metallurgical Literature 187
A New Ampere-Hour Meter 191
The Analoid Method for the Determination of Phosphorus in Steel, Iron and Slag Magnesium 191
Sentinel "Pyrometers" and Paste and Their Uses 192
A Special Paper for Recording Instruments, Drawings and Similar Purposes 193
Bronze Castings as a Substitute for Steel Parts 193
Portable Welding Outfit for Metallurgical Works 194
The Iron and Steel Market 194
Personal 196
Digest of Electrochemical U. S. Patents 196
Book Reviews 197

Copper and the Flotation Process

One of the most suggestive points in Mr. Mathewson's notes on present tendencies in copper metallurgy, published elsewhere in this issue, is the effect of concentration by flotation. From its position as an intermediate process between gravity concentration and smelting, flotation exerts an influence in both directions. In ore-dressing it has proved the method par excellence for concentrating slime. Hence the production of slime in crushing and grinding for gravity concentration is no longer the bugbear that it has been in recent years. A natural conseequence is an increased production of fine concentrates unsuited to blast furnace treatment, but reverberatory smelting removes any difficulty on this score. The efficiency of flotation, plus the improvements in reverberatory smelting, is modifying milling ideas by reducing the upper limit of size at which gravity concentration has been practiced. The combination points to more fine grinding and slime concentration, and the relegation of the blast furnace from its eminent position.

Another interesting possibility is the effect of flotation on leaching processes. At a time when hydrometallurgy is just getting its stride and finding acceptance among metallurgists, flotation rises as a definite competitor and threatens the popularity of copper leaching. Progress in flotation is being made so rapidly that the actual application of leaching processes may halt to await developments. With such results as flotation has shown at Anaconda it may be a question whether the elaborate roasting-leaching process developed there will be long continued. In the case of oxidized copper ores also, flotation may forestall leaching if the process of converting carbonates and oxides to sulphides, and floating the latter, is successfully developed. Further, while leaching may be profitably applied to certain ores, the character of ore-bodies changes with depth and oxidized ores give place to sulphides or mixtures which will be unsuited to leaching but may be amenable to flotation.

Flotation is still in the empirical stage of development. Its success in one place is no criterion of the possible results at another. Its usefulness must stilll be determined wholly by experiment, varying the conditions as to oil, acid, temperature and combinations of these elements. But enough has already been done to show that it is a tremendous factor in ore treatment and that opportunity still awaits the investigator. When the horizon of the flotation process is happily clear of the clouds of legal patent litigation, progress should be more rapid and knowledge more widely disseminated.

The War and American Iron Trade

The European conflict has exerted a very slight influence upon the general course of the iron trade of the United States. The result is quite opposite to the expectations entertained in many quarters last August, when predictions were made of a rapidly expanding export trade, or quite contrary expectations entertained in other quarters in September and October, that business in the United States would be so paralyzed that there would be no domestic demand. Indeed, the whole course of events has been to illustrate in striking manner the unwisdom of making predictions when one is not acquainted with the circumstances.

Last August the view was very commonly expressed that here was the golden opportunity for the United States to build up a large export trade in iron and steel. It was unfortunate that we had not captured the trade already, but here was the opportunity to make up for lost time. The experience of only a few months has shown that if the United States had had a large export trade it would have suffered more severely than it did, for in the past few months the total demand for iron and steel among all the non-producing countries has been but a small fraction, probably less than one-quarter of what it was before the war. With Germany, Belgium, and France practically out of the competition, England's iron and steel exports have decreased by about 40 per cent, and the exports of the United States by about 20 per cent, even though in the case of the United States the exports have been swelled somewhat by demand for war material.

The immediate effect of the war was a stringent curtailment of iron and steel demand in the United States, but the demand in the past two or three months has been decidedly better and if the current demand is continued for two or three months longer the domestic demand in the United States for the full period since the war started will be approximately as large—or as small—as it was in the corresponding period before the inception of the war. The American iron trade was already in a state of almost acute depression.

In one respect there is still the possibility of the war having an acutely unfavorable influence upon the American steel trade, this possibility arising from the ferromanganese situation. Several months ago England placed an embargo upon the exportation of ferromanganese, subject to certain limitations which it was supposed would be easily met. American steel manufacturers were asked to sign an agreement that if they should receive English ferromanganese they would not export steel to certain designated countries, but the concerns that signed the agreement are still awaiting shipments. They have lately been approached with a fresh proposition of "marrying contracts" by purchasing additional ferromanganese at $68, in return for which they will be furnished equal tonnages of the alloy on their old contracts, made at from $35 to $38. The dollar looms so large in the negotiations that there now seems little doubt but that American steel makers will be able to secure ferromanganese when they are ready to pay the price.

There is another question, of magnesite for basic open-hearth furnace use, hitherto imported from Austria, but no serious apprehensions are entertained on that score. Altogether, the American iron and steel industry has suffered wonderfully little dislocation as to its raw materials and supplies from the European war, and there is much cause for congratulation that it proves to be so almost completely self-contained.

Taking Care of the Human Element

The passing from "first aid" to "safety first" is typical of the increasing attention now being paid by mining and metallurgical companies to the welfare of the human element in their operations. Just as they are now seeking to prevent accidents and avoid injuries by anticipating their possible occurrence through preventive measures, rather than offering remedial aid after accidents have happened, so also are they forestalling dissatisfaction and eliminating labor troubles by administering to the social welfare of their employees.

Seldom has any humane movement found such ready and world-wide acceptance as has been accorded to "safety first." Following less rapidly in its wake has come the less pretentious but equally important welfare movement for better sociological conditions. Perhaps the sequence is natural. Physical injury or fatal accident obtrudes itself on our attention, and its cost is definite and tangible. Social malaise and discontent cannot be expressed mathematically; and because it makes a less broad and striking appeal to human sympathy, its ill effects on industry have not been so apparent.

The good work of the pioneers in welfare work, however, has sharpened the perception of the great majority of large operators. Consideration for the human element, wherever it has been conscientiously observed, has been shown to yield tangible results in continuous and faithful service and efficient performance of duty. It has created the spirit of pride and loyalty so essential to the maintenance of effective organization, so that instances are not lacking where contented employees have been deaf to the arguments of unwise agitators. In fact, it has been apparent that by anticipating the welfare of employees, stimulating and directing their mental and social activities, prudent companies have forestalled dissention and avoided labor troubles.

The welfare work of the Homestake company in South Dakota is a conspicuous example. Under the direction of the late Thomas J. Grier, this company has shown commendable interest in the life and activities of its employees. Among the institutions established by the company is the hospital, the service of which is free to employees and their dependents. One thousand dollars monthly is contributed to an aid fund, to which the 2500 employees add one dollar each per month. This fund provides accident, sick and death benefits. For the wholesome amusement and recreation of employees, a large hall was erected by the company at a cost of $300,000. This contains also the Hearst free library.

Co-operation between industrial companies and the Y. M. C. A., which has been so effective in railroad work,

has been of benefit to mining companies. By agreement with this organization, companies are enabled to provide a social center for employees and their families, affording a place to spend time profitably and away from vicious influences. Such centers ultimately supply all the social needs of the community, as well as affording educational facilities. The Bunker Hill & Sullivan company has established at Kellogg, Idaho, an industrial Y. M. C. A., erecting a building at a cost of $35,000 and contributing $1500 annually to its support. Members pay an annual fee as in similar institutions elsewhere. This center serves at once as a social club, a meeting place for the labor organization and a night school. It is equipped with gymnasium and baths, billiard and game rooms, bowling alleys and public library. That it warrants support and has contributed materially to the welfare of employees, is the testimony of company officials.

Examples could be multiplied. The Copper Queen company in Arizona administers an employees' benefit fund to which it makes an annual contribution of $7500. This voluntary association of employer and employees has been found useful in spite of the adoption in Arizona of a compulsory workmen's compensation law. The Hollinger company at Porcupine adopted over a year ago a system of "loyal service" bonuses to day-wage employees without distinction save as to term of service. In 1914 this bonus amounted to nearly $12,000. It is based on a graduated scale of remuneration according to the term of employment. Men in service for over a year receive a bonus of fifteen cents per day; over two years thirty cents and over three years forty-five cents. At most of the large mines and metallurgical works that have come into existence during the last few years, some sort of provision has been made for the welfare and prosperity of the employees. In most cases the isolation of mine, mill or smelter has made necessary as well as advisable, the maintenance of clubs, places of recreation, model and sanitary homes, and participation in various kinds of benefits.

The Pyrophoric Alloy Decision

The final decision in the pyrophoric alloy litigation, as rendered by the United States Circuit Court of Appeals and printed elsewhere in this issue, is of considerable importance to the chemical industries, and particularly to those manufacturing alloys, both because of the chemical questions which it settles and the legal doubts which it terminates.

Considering the latter point first, the claim of the Welsbach patent involved in the litigation was for a pyrophoric alloy containing cerium alloyed with iron, while the specification mentioned nickel and cobalt as alloying metals, and also spoke of using iron or its equivalent, in making the alloy. The legal question was as to whether the claim of the patent, naming specifically only iron, was competent to cover any other alloying metal or metals; or, generalizing the question, as to whether a claim covers more than it specifically names, and may be extended to their fair equivalents. On this point the court rules that the patent being a pioneer invention is entitled to a liberal application of the doctrine of equivalents, which does not confine a patentee to equivalents which he has expressly referred to, but allows him any other fair equivalents unless he has himself restricted his claim by some statements in his specification. The specification of the Welsbach patent did indeed state that one of the metals in the alloy must be a rare-earth metal, among which metals cerium was relied on as essential to the composition of the alloy, thus restricting the claim on the cerium side; but the specification placed no restriction upon the other constituent, the iron side of the alloy, other than to specify that it must be a non-rare-earth metal; that is, not be a metal of the rare-earth class. This negative restriction led the court to the conclusion that each and every metal not of the rare-earth class must be considered as a fair equivalent for the iron in the Welsbach alloy, as long as it acts in a similar manner when alloyed with cerium. This extension of the field of a claim of a basic patent to cover all fair functional equivalents, even when not specifically named, and even when the claim does not speak of equivalents, is the first important point of the decision.

The second point, the chemical question at issue, was as to whether the term "equivalent" should mean, in the case of this alloy, as concerned the term "iron or its equivalent" in the specification, an element chemically related to or chemically equivalent to the iron, or should connote equivalency of function, or equivalency of result when used in the alloy. The respondent had strenuously urged that the equivalency in question must be regarded as chemical equivalency, and the metals replacing iron be limited to the metals associated with iron in the periodic system, such as nickel, cobalt and possibly manganese. The complainant, however, urged that such chemical equivalency had no meaning in the field of alloys and was absolutely without certainty or value in determining equivalency in producing a given desired result or property of an alloy. This position and principle were accepted without reserve by the court, which ruled that the equivalency of other metals with iron is to be found not in their chemical structure, but in their functional efficiency when combined with cerium in a metallic alloy. If this ruling is generalized it means that in an alloy, or in fact any chemical compound, protected by a patent, the "equivalent" of any claimed ingredient of the same is another element which acts functionally and with efficiency to create the same valuable property of the product, to an industrially useful degree. Such a functionally equivalent element may or may not be chemically related to it, or chemically in the same family of elements; whether it is or not is not the determining factor in considering equivalency in the sense of patent law. The law considers only functional efficiency; that is, capability, of acting to a useful extent, to produce the same result.

Owners of chemical and metallurgical patents and prospective applicants for the same should mark, learn and inwardly digest this interesting decision, because of its fundamental bearing upon the scope and meaning of "equivalents" in this class of patents.

Readers' Views and Comments

The Action of Fluorspar on Basic Open-Hearth Slags

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In your issue of January, Mr. W. S. Hamilton proposes a theory to explain the great effect additions of fluorspar have upon the fluidity of basic open-hearth slags. There is no necessity of resorting to speculation, as the research of Karandief, published in the *Zeitschrift für Anorganische Chemie*, 1910, LXVIII, 188, has shown that $CaSiO_3$, melting at 1501 deg. C., forms an eutectic, with 38.2 per cent CaF_2, which freezes at 1130 deg. C.

H. O. Hofman.

Institute of Technology,
Boston, Mass.

Examination of Fire Bricks

To the Editor of Metallurgical & Chemical Engineering.

Sir:—I feel that a comment might be in order on the determination of titanium, as referred to under the title "An Examination of Fire Bricks," by W. Hamilton Patterson, in your February issue.

A procedure that I have found to give excellent results, with comparative ease of operation, is modelled largely after the method described by W. F. Hillebrand in Bulletin No. 422, U. S. G. S. The weight of silica previously obtained is corrected for the total residue, after treating with hydrofluoric and sulphuric acid. The precipitate containing aluminium, iron, etc., is then weighed in the crucible still containing this residue. Two or three grams of potassium pyrosulphate are then added and the alumina precipitate is dissolved in the fusion.

The melt is dissolved in dilute sulphuric, and any silica which has come down with the alumina remains insoluble. This should be weighed and added to the previously found weight of silica.

Care should be taken not to use too much heat in dissolving the melt, as titanium is sometimes precipitated if present in large quantities. The solution may then be split into two portions, determining iron in one and titanium in the other; or, if the iron is determined by zinc reduction and permanganate titration, titanium may be determined in the solution after this titration.

This method takes care, almost automatically, of the possible impurity of either the silica or alumina precipitate and insures the presence of all of the titanium in the sulphuric acid solution, whether or not any of it has been carried down previously with the silica.

J. S. Beckett.

Cranford, N. J.

Fused Silica Dishes for the Concentration of Sulphuric Acid

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In your January issue there is an article by Mr. William Mason on the concentration of sulphuric acid in cascade-type plants using fused silica dishes.

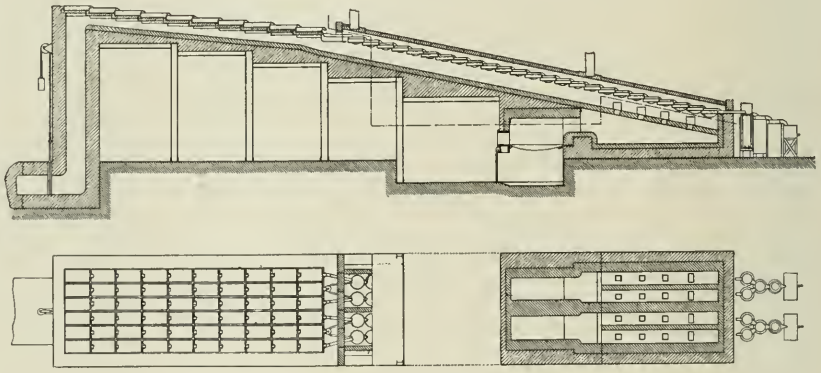
The description of the concentrator and the conclusions which are drawn are not applicable to the standard type of plant in general use, and as the production of concentrated sulphuric acid either from chamber acid or by-product acid, resulting from nitrating processes, petroleum treatment, etc., is of considerable interest at the present time, I would request the courtesy of space in which to outline the history and present status of fused-silica-dish-type concentrators.

The genesis of continuous cascade concentrators is undoubtedly the continuous glass retort system patented by Henry Chance in 1871. This system, which was in extensive use in England for many years, consisted of four or more glass retorts arranged in cascade, over a gas or coal fired furnace. The retorts were provided with glass connections, so that the weak acid fed into the top retort could flow through the other retorts, meanwhile undergoing gradual concentration. The acid drawn off from the last retort was led into a cooler, and thence into storage tanks or carboys.

The breakage of retorts was a serious figure in the operating costs, but the system survived owing to its low installation cost compared with platinum.

Attempts were made about 1887 to replace the glass retorts with porcelain, but the porcelain retorts were costly and gave no better results.

The next development came in 1889 when Négrier built a furnace, using porcelain dishes in place of the retorts, and a fume chamber of acid-proof brick over the dishes in place of the top of the retort and its connecting pipe. The Négrier furnaces were of small capacity and were superseded about 1900 by the Benker and Hartman system which made use of forty-eight porcelain dishes combined with a set of lead pans to utilize the waste heat and incidentally to carry the concentration from 50 deg. Beaume to 58 deg. Beaume.



PLANT FOR CONCENTRATION OF SULPHURIC ACID

The Benker and Hartman system gave fairly good results, but the breakage of porcelain dishes was a frequent cause of trouble, while the fuel efficiency was lower than other types of concentrator which came into use about the year 1906.

With the invention of vitreosil (fused silica) in 1906, and its development toward apparatus of commercial size in 1907, the cascade concentrator system took on a new lease of life, so that at the present time there are more vitreosil units in use throughout the world than any other type of concentrator.

The introduction of vitreosil dishes removed the two most serious faults of the porcelain concentrators, excessive breakage and low fuel economy, and enabled the design to be improved by substituting a single fire in place of the three used on the Benker-Hartman plants.

The breakage of porcelain dishes was caused through uneven heating or the slowing down of the feed and chilling of the dish when the feed was turned on full

again. By reason of its low coefficient of expansion (0.54×10^{-6} or one-sixth that of porcelain) vitreosil dishes do not break through temperature changes no matter how severe, as is well evidenced by the usual lecture-room experiment of plunging a white-hot vitreosil crucible into cold water without breakage occurring.

Occasionally in the operation of vitreosil concentrators, the feed has been accidently shut off, the acid boiled out of the dishes, and then the full feed turned on again into the red-hot dishes without a dish being cracked.

This resistance to temperature changes permitted the vitreosil dishes to be directly exposed to the fire gases in open seatings, instead of being protected with 2-in. fireclay slabs, which, of course, gave a greatly increased fuel economy.

The position of the firebox and the type of furnace has been a source of continual experiment and the plus pressure furnace referred to by Mr. Mason has been tried out by two factories only, as it was not found possible to get the temperature regulated over the whole length of the concentrator.

Natural-draft furnaces burning soft coal have given the best results and are in general use. Furnaces burning fuel oil and natural gas are also used, but the construction is similar to the soft-coal furnaces.

The illustration on page 136 shows the general outline of a unit to produce 20,000 lb. 66 deg. Beaume per twenty-four hours from 50 deg. Beaume H_2SO_4 and shows clearly the furnace position and arrangement of firing flues. This unit contains 100 dishes (12¼ in.) and sixty pans (24 in. by 12 in.) used in place of lead preheating pans. All the pans and dishes, excepting the last three in each row at the exit end of the plant, are supported in open seatings and are directly exposed to the fire gases. The last three dishes have closed seatings, as experience has shown that with open seatings at this point, the acid boils strongly, with loss of SO_3 and spurting of liquid on to the seating. The breakage of lower basins referred to by Mr. Mason was in all probability due to the use of open seatings. The acid spurted over would come into contact with the seating and the asbestos rope gasket, and gradually form a solid mass. The contraction of the seating with a slight cooling of the plant, would break the basin unless it was free to rise and fall on its gasket, as the relative coefficients are as 1 is to 14.

Units such as shown in the cut will concentrate 50 deg. Beaume H_2SO_4 to 66 deg. Beaume, with an average fuel consumption of 17 per cent of 13,000 B.t.u. soft coal, consumption being based on the weight of finished acid. The breakage of dishes in fifteen factories for which accurate records are available, has always been under 5 per cent per annum from all causes, while the failure of preheater pans is less than 1 per cent per annum.

The first silica-basin concentrator was installed in 1907 and at the time of writing upward of 500 complete units are in use throughout the world, thus indicating the value of the vitreosil dish system.

A considerable proportion of these plants handle recovered acid containing traces of nitric or organic acids, as vitreosil is attacked only by hydrofluoric acid.

Within the last year several units have been put up for the continuous concentration of solutions, either containing free acid or substances which will attack iron, lead, etc., and providing the solution is run off before crystallization takes place, excellent results can be obtained.

Albert E. Marshall,
Manager, The Thermal Syndicate, Ltd.
New York City.

Quantitative Blowpipe Analysis

To the Editor of Metallurgical & Chemical Engineering:

Sir:—Returning from a two months' trip to Panama and the West Indies, my attention has been attracted by the two well-written and instructive articles on the above subject by Mr. Fischer, in your November and December issues, 1914. Mr. Fischer does not exaggerate unduly the usefulness of these aids to the prospector, but he has exaggerated somewhat my personal contribution to the advance of this art. I refer particularly to being credited with devising the useful little scale of alloys of gold and silver. This was devised by my own instructor in the art, Dr. Victor Goldschmidt of the University of Heidelberg; my own contribution was merely the suggestion of a brass case with screw top to ensure safe carriage of the scale in the prospector's kit.

Joseph W. Richards.
Lehigh University,
South Bethlehem, Pa.

"Limitations of the Electric Furnace in the Manufacture of Steel Castings"

To the Editor of Metallurgical & Chemical Engineering:

Sir:—On page 110 of your February issue Mr. G. Muntz, in the article of "Limitations of the Electric Furnace in the Manufacture of Steel Castings" refers to my article in *The Iron Age* of March 27, 1913, as one which contained statements which were the products of enthusiasm and at variance with actual facts. Not one word of evidence was given to substantiate this statement and no statement in my article was even mentioned.

Mr. Iver Rennerfelt, on page 582 of your September issue, quoted me correctly and gave the facts that are recognized by nearly all metallurgists. Those that know about the manufacture and casting of steel know that the Bessemer converter was a wonderful invention for cheapening the manufacture of steel and giving it a field of usefulness that it did not have before that time. No one argues that the Bessemer converter makes as good steel as the open-hearth furnace. Likewise no metallurgist claims that the open-hearth furnace makes as high-grade steel as the crucible or electric furnace in commercial quantities. Metallurgists also know that the converters, used in steel foundries, are modifications of the Bessemer process and cheapen the production of steel castings but do not improve their quality.

The most foolhardy foundrymen would not attempt to use the steel coming from a converter to cast the wheels, with hollow spokes and rims, which I illustrated in that article in *Iron Age*, and guarantee them to be absolutely free from blow holes. Wheels that were 24 inches in diameter were cast with walls but ⅛ of an inch thick and with ½-inch fillets where the spokes join the rims. Only ⅛ in. was allowed for finishing the face and sides of the rims and the hubs.

In that article I described, in detail, why such castings could not be made commercially from steels melted and refined in converters, or even in open-hearth furnaces, and yet Mr. Muntz did not mention even one of these, to say nothing of refuting them. Not being retained by any steel maker or furnace builder, I was free to express all the facts that my investigations presented. Anyone capable of appreciating it, should be enthusiastic over a fine piece of work. That is positively no argument against the facts I gave as to how these castings were made, or how they could and could not be made.

In the *American Machinist* of Dec. 13, 1908, I described and illustrated some steel castings made by the Flexilis Works in Germany that were even better than

these. An exhaust manifold for an automobile engine was cast by them in lots of 500. It was 22 inches long with a 1½-inch pipe. Its center was water jacketed with a ½-inch space and an outside diameter of 2¼ inches. All the walls were cast 3/16 of an inch thick and the flanges were given ⅛ of an inch finish. Steel cylinders 12 inches diameter and 18 inches long, with outside ribs, were cast with ¼-inch walls. All the fillets were ¼-inch and the finish on the cope end was but 3/16 of an inch. Many other castings of a similar nature were shown and they were all guaranteed to be entirely free from blow holes.

They would also cast them from any steels with any carbon content desired and also from any of the high-grade alloys.

This story was doubted and called enthusiasm by American foundrymen using converters and open-hearth furnaces until an American foundry, using crucible furnaces and the German methods, began to market a similar product. It would be suicide for any foundrymen to attempt to make steel castings to such specifications, at a commercial price, from converters or open-hearth steel. Blowing air through iron to reduce the carbon content to that of steel, as the converter does, cannot reduce the oxides, nor does it reduce the sulphur and prosphorus to as low percentages as will be found in steels coming from the crucible or electric furnaces.

Metallurgists that have not become commercialized will not claim that these and other impurities can be commercially reduced to as low percentages in converter steel as in those made in crucible, electric or even open-hearth furnaces.

I do not want to be misunderstood by the thought that I am condemning the converter entirely. Modified Bessemer converters, either of the Bradley Stoughton or Tropenas type, have been of great benefit to the steel casting industry and will continue to have a large field of usefulness. But when one tries to argue that they make better steel than the crucible or electric furnaces he expresses things that are at variance with the vast amount of data that have been compiled nnd published about steels in the past few years. Some very high-grade steels can be made in the open-hearth furnace by using three or more slags for purifying the metal and materials that act as scavengers, but this adds considerably to the cost and might make the steel more expensive than that which is made in electric or crucible furnaces. Likewise, more time and materials might be used to make converter steel of a higher grade than is now the case, but the impurities cannot be removed as thoroughly as by the processes used in other furnaces. Where cost is a big factor the converter becomes a very important tool, but when quality is the main consideration other furnaces give better results.

Detroit, Mich. E. F. Lake.

Tube-Mill Tonnage Calculation

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I was much interested in Mr. A. H. Jones' very complete discussion of my tube-mill tonnage formula, in your February issue. I should have pointed out in my original discussion in your January issue that any mesh can be used as the basis of the calculation; thus it can be based upon plus 28-mesh as Mr. Jones has done in his illustrative calculation.

I instanced minus 200-mesh, as to most millmen "per cent. minus 200" carries a distinct meaning; knowing the minus 200 one can reconstruct the approximate screen test of any normal ore, and no other size gives the same general information. The numerical expression for ratio of tube-mill tonnage to battery tonnage, based upon the plus 28-mesh from Mr. Jones' screen tests is:

$$\frac{T}{B} = \frac{d-a}{c-b} = \frac{0-41.8}{0-21.8} = 1.91$$

as he correctly calculates it. However, if his sampling and screen tests are accurate, the same formula applied to his minus 200-mesh should give the same ratio. The numerical expression based upon minus 200 in his screen tests is

$$\frac{T}{B} = \frac{d-a}{c-b} = \frac{72.3-21.2}{28.1-6.5} = 2.39$$

I have tabulated below Mr. Jones' screen tests with an added column giving the ratio of tube-mill tonnage to battery tonnage as calculated for each size of screen by my formula.

Table II from Mr. A. H. Jones' Discussion

Mesh	Battery Discharge Per Cent a	Tube-Mill Feed Per Cent b	Tube-Mill Discharge Per Cent c	Dorr Overflow Per Cent d	Ratio Tube-Mill Tonnage to Battery Tonnage $\frac{d-a}{c-b}$
10	10.3	5.4	....	....	1.91
14	10.0	5.2	....	....	1.92
20	10.2	5.3	....	....	1.91
28	11.3	5.9	....	....	1.92
35	7.7	4.9	1.0	....	1.97
48	7.1	6.5	3.1	....	2.09
65	5.6	8.1	6.5	....	3.50
100	6.0	20.0	20.0	1.0	....
150	6.6	24.4	28.6	12.5	1.40
200	4.0	7.8	12.7	14.2	2.08
—200	21.2	6.5	28.1	72.3	2.37
				Average	2.11

It will be noted that the individual calculations do not check very well, and my experience has been that screen tests from samples taken over a period of only a few hours are very apt to be misleading. Segregation is the salient feature of the tube-mill-classifier closed circuit, and a very slight adjustment of the batteries may introduce irregularities which take hours to become readjusted. Samples taken carefully over a considerable period of time will give approximately the same calculated ratio of tube-mill to battery tonnage for each mesh.

For this purpose, daily routine sampling is best, the samples being taken by the mill crew and the screening being done in the laboratory. One has a check on the accuracy of the work by applying the formula to each mesh.

I regret that I have not with me at this writing any screen test records. Certainly publication of a series of screen tests such as Mr. Jones gives, for a number of mills, would be a very valuable addition to technical literature and would throw an interesting light upon the milling of various ores.

Douglas, Ariz., Feb. 16, 1915. Noel Cunningham.

The Western Metallurgical Field

Platinum Milling in Wyoming.

In our issue of February 1911, page 75, was described the concentration of platiniferous ore at the Rambler mine in Wyoming. The work as then described was continued for some time, but the mill was subsequently closed and a period of inactivity followed. Several months ago, however, work was renewed by the Platinum Mining & Milling Co., an organization of stockholders under the management of Mr. Julius Thielman, which leased the property. For the past two months the 50-ton mill has been in operation, concentrating the dump ore, and the first shipment of concentrate was to have been made during February. According to Mr. Robert A. Marr, metallurgist for the company, the concentrate contains platinum, palladium, iridium,

osmium, gold, silver and copper. At the rate of milling, the dump contains sufficient ore for one year's operation, and there is still ore in the mine which will be kept in reserve.

Several interesting changes have been made in the milling system since the work was described four years ago. Chief among these is the use of a Peck centrifugal concentrator. This machine is of a different type than the one used experimentally at Anaconda. The latter was of the vertical type, while the one under consideration is horizontal. The ore is ground to 60-mesh in a Hardinge pebble mill working in closed circuit with a drag classifier, the oversize being returned for regrinding. Following the drag classifier is a 60-mesh screen which finally limits the size of the pulp particles. Its principle function, however, is to remove wood pulp or other foreign matter that would interfere with the operation of the concentrator. The Peck horizontal-type centrifugal concentrator is the only one of its kind in use, and handles the entire product of the crushing department, producing concentrate and tailing. In order to insure a pulp of uniform density for the concentrator feed, the ground ore is kept in agitation in a tank fitted with paddles.

In the early operation of the mill considerable difficulty was encountered from the acidity of the ore. Some of the copper occurs as sulphate, and there are other soluble forms. The mill water, becoming impregnated with acid copper salts, corroded screens and metal work throughout the mill, causing delays and increasing cost of operation. In order to overcome this difficulty the present management is adding from five to six pounds of lime per ton of ore at the crusher, so that the mill water is alkaline. This corrects not only the acidity of the ore, but also of the mine water which is now being used for milling.

Milling Results at Magma Copper Mine.

The Magma Copper Company, developing a large low-grade copper mine in Arizona, has had in operation at the mine a mill of 150 tons daily capacity for the purpose of testing milling methods. A combination of water concentration and oil flotation is in use. The recovery of copper, including ore sorted by hand, has averaged over 85%. During the year ended December 31, 1914, shipments of picked ore and concentrates amounted to 5474 tons, averaging $1.90 gold and 22 oz. silver per ton, and 20% copper. The product has been hauled by teams about 32 miles to Florence, Arizona; but at present a narrow gage railroad is under construction from the mine to Webster, a point on the Arizona Eastern Railroad, about 31 miles from the property.

Quicksilver in Nevada.

The Nevada Cinnabar company has recently begun the treatment of mercury sulphide ore at its mine at Ione, Nevada. The main feature of the plant is a 50-ton Scott continuous roasting furnace, with supplementary equipment in the form of condensers and refinery. The ore is crushed to 1½ in., dried in a rotary dryer and then charged in the furnace. The temperature is maintained at about 1000°F. Mercury distills and passes from the furnace through side ports to a dust chamber and thence to the condensers. Of the latter there are eight independent sets of two chambers each, connected by terra cotta pipes. The condensers are cleaned through doors suitably arranged. About 30% of the mercury recovered runs from the condensers, but the remaining 70% is retained by heavy carbonaceous matter or soot. The entire product from the condensers is moistened and placed in a pan that is heated to a low temperature by means of steam. The mixture is then worked with a hoe which causes the mercury to coalesce and run free from the soot. A rotary machine designed to perform this operation mechanically is soon to be installed. The condensed product from the last few sets of condensers contains considerable moisture. In the treatment of this product, ashes, lime or other dry alkaline material is added in order to reduce the moisture content and at the same time cut the greasy film that prevents the globules of mercury from running together. Altogether about 90% of the mercury condensed is recovered, and the balance together with the soot is recharged to the furnace in small quantities. As the plant has been in operation only a short time, and no complete clean-up has ben made, it is impossible to indicate the percentage of extraction.

Federal Mining Experiment Stations.

A bill introduced in the House of Representatives by Congressman Foster, chairman of the House Committee on Mines and Mining, and known as House Bill 15869, has been passed by that body. It provides for the establishment of ten mining experiment stations and fifteen mine safety stations in the several important mining districts of the United States and Alaska, under the direction of the Bureau of Mines. The function of the mining experiment station is to investigate conditions and suggest improvements in the mining industry, preventing unnecessary waste of resources, and generally contributing to the advancement of the industry. No appropriation is mentioned, but it is understood that $750,000 will be required to make the act effective. Provision is made, however, for accepting "lands, buildings or other contributions from the several States offering to co-operate in carrying out the purposes of this Act." It now seems possible that the bill will be passed by Congress at this session. It would have been better if the sum of $750,000 could have been placed at the disposal of the Bureau of Mines without making it necessary to dissipate a considerable portion of the sum in the maintenance of so many stations; but it appears politically necessary to accept these conditions in order to make an entering wedge for some federal support to mining.

Company Reports

The Wellington Mines Co., operating mine and mill at Breckenridge, Colo., makes the following report for the year ended November 30, 1914. Developed ore amounts to from 45,000 to 50,000 tons, containing from 4 to 5% lead and 17 to 18% zinc. The wet concentrating mill was idle during six months of the year, and was thoroughly overhauled, the capacity being increased to 125 tons daily. The magnetic mill also was closed during April for repairs. A Hardinge ball mill and another magnetic separator have been added to the equipment, giving a better recovery of both lead and zinc. The wet concentrating mill treated 17,430 tons of ore, averaging 17.4% zince and 4.98% lead, producing 1106 tons of concentrates assaying 34.8% lead (dry), and 9145 tons of middlings assaying 24.13% zinc, 2.46% lead and 27% iron. The magnetic mill treated 8172 tons of this middling, producing 3657 tons of concentrates assaying 46.14% zinc and 83.9 tons of lead concentrates assaying 64.1% lead. In addition to this, the magnetic mill treated during the first five months of the year 6820 tons of middlings assaying 18.62% zinc and 3.44% lead, producing 2028 tons of 47.75% zinc concentrates and 161 tons of 65.2% lead concentrates. The tailing from the magnetic mill carries 53% iron and some gold, silver and lead, but it cannot be marketed on account of high freight rates.

Nevada Consolidated Copper Co. has issued its

fourth quarterly report showing the production for the year 1914.

The copper output during the four quarters was as follows: 15,597,592 lb; 14,322,807; 11,258,421; 8,065,-236. During the fourth quarter the property was operated on a basis of 50% normal capacity. The tonnage treated was 416,825 and the grade 1.54% copper. The cost of copper, crediting miscellaneous earnings, was 8.42 cents per pound. After payment of the 20th dividend, there was a deficit for the quarter of $378,949. The physical assets of the Steptoe Valley Smelting & Mining Co. having been acquired by Nevada Consolidated in August 1914, the former was legally dissolved in November 1914.

Chino Copper Company's report for the fourth quarter of 1914 shows a production of 8,935,585 pounds of copper, as compared with 17,288,678 pounds in the first quarter. The average daily tonnage treated in the fourth quarter was 3774 as against 6469 tons in the first quarter. The total copper production for the year 1914, including copper contained in crude ore shipped, was 56,841,977 pounds. The average grade of ore treated in the fourth quarter was 1.8612% copper as against 2.1653% for the third quarter. The average extraction was 69.14%, as against 68.04% for the previous quarter. The ratio of concentration was 19.82 to 1. The cost per pound of copper, without allowing credits from other sources, was 8.14 cents. Credit for gold amounted to 0.12 cents per pound. With all miscellaneous earnings credited, the cost per pound was 7.71 cents.

Ray Consolidated Copper Co. shows a production of 9,563,113 pounds of copper during the fourth quarter of 1914, as compared with 17,707,374 pounds in the first quarter. The ore milled during the quarter amounted to 402,917 tons, averaging 1.74% copper. Average mill recovery was 68.2%. Milling costs were 54.56 cents per ton, compared with 45.85 cents for the previous quarter, the increase being due to the decreased tonnage. Average coarse crushing cost was 2.666 cents per ton, and mining cost 49.722 cents. Net cost of copper was 8.748 cents per pound; crediting miscellaneous income it was 8.645 cents.

Utah Copper Company's fourth quarterly report for 1914 shows a production of 20,229,012 pounds of copper, as compared with 40,017,562 pounds in the second quarter. The gross production for 1914 was 121,779,-401 pounds; for 1913, 119,939,809 pounds. The quantity of ore milled in the fourth quarter was 1,035,303 tons, all at the Magna plant. The average grade of the ore was 1.5062% copper. Extraction was only 64.86%, as compared with 68.13% in the previous quarter. The reduction was due to carbonate of copper in the ore. The average cost of copper for the quarter was 7.731 cents per pound, crediting miscellaneous income it was 6.688 cents. The financial statement shows a deficit for the fourth quarter of $142,293.

The Wolverine Copper Mining Co., Michigan, gives the following data on operation in the annual report for the year ended June 30, 1914. Ore stamped amounted to 182,127 tons, from which 4,606,015 pounds of mineral was recovered, yielding 3,435,459 pounds of refined copper. Cost per ton of ore stamped, $1.92; cost per pound of refined copper at the mine, 9.85 cents; total cost refined copper, 11.3 cents per pound.

The annual report of the **Coniagas Mines Ltd.**, Cobalt, Canada, for the year ended October 31, 1914, states that the year was not so profitable as the preceding three years, owing to the low price for silver, the diminishing output of high-grade ore and the dislocation of business due to the war. No valuable discoveries were made on outside claims staked by the company. The annual bonus to employes at Christmas time amounted to 4% of their annual earnings, or $8,682. The concentrating mill treated 54,522 tons of ore, averaging 24 oz. silver per ton, at the rate of 2.93 tons per stamp. High-grade concentrates shipped amounted to 496.4 tons, averaging 2030 oz. silver per ton; low-grade slime amounted to 251.8 tons, averaging 151 oz. Mine ore shipped amounted to 493 tons averaging 2944 oz. Sand tailings from the mill averaged 3.18 oz. silver per ton, and slime tailings 6.66 oz. It is estimated that the ore reserves contain 14,880,000 oz. silver.

From the report of the **Mount Morgan Gold Mining Co.**, Queensland, Australia, for the half-year ended November 29, 1914, the following data are taken. The concentrator handled 31,274 tons, recovering 87.4% of the copper and 77.5% of the gold. The smelter treated 179,939 tons. The production was 4593 tons of refined copper and 58,309 oz. gold. The new smelting furnaces were started in July, two being in operation and one held in reserve. Some difficulty has been experienced in handling flotation concentrates, but experiments have indicated a solution of the problem, which, however, is not stated in the report.

The annual report of the **Hollinger Gold Mines, Ltd.**, of Ontario, Canada, shows that $2,688,354 was recovered from milling 208,936 tons of ore of an average value of $13.67 per ton. The gross profits amounted to $1,786,-680. Dividends paid amounted to $1,170,000. The mill was in operation 92.2% of possible running time, and handled an average of 633 tons per 24 hours of running time. The stamp duty was 13.30 tons per 24 hours. Chemical consumption per ton of ore: cyanide, 0.525 lb.; lime, 1.557 lb.; zinc, 0.532 lb.; acid, 0.216 lb.; lead acetate, 0.0031 lb. Average value of pregnant solution, $5.698. During the year there was stacked for retreatment 6062 tons of concentrates of an average value of $8.85 per ton. The rapid development of the property has necessitated enlarging the mill, and it is expected that 100 stamps will be dropping by the middle of March 1915. Continuous decantation has been adopted for a considerable tonnage of ore treated. Distribution of milling cost is as follows, based on total tonnage treated and including 2910 tons of ore milled for the Acme company. If based on Hollinger ore only, 208,936 tons, the cost is $1.22 per ton.

Account	Per ton
General milling charges	$0.054
Superintendence	.047
Tailings disposal	.018
Lighting	.011
Heating	.039
Shoveling in bins	.012
Crushing	.079
Conveying	.034
Stamping	.160
Classification and tube-milling	.188
Concentration	.062
Handling concentrates	.007
Treating concentrates	.032
Handling pulp	.040
Thickening	.014
Continuous decantation	.031
Filtration	.103
Neutralizing	.012
Clarifying and precipitation	.063
Refining	.059
Pumping solutions	.021
Cyanide	.083
Cleaning mill	.019
Alterations	.034
Assaying	.015
	$1.237

Present Tendencies in Copper Metallurgy

BY E. P. MATHEWSON
General Manager, Anaconda Copper Mining Company

Finer Grinding in Ore Dressing

In ore dressing, the flotation process is finding a vast field in sulphide copper ores, particularly those in which the sulphide minerals are finely disseminated. Numerous processes, so-called, are being placed on the market and a great variety of flotation machines. A number of these machines have given marvellous results, giving a tailing as low as 0.08 per cent copper, this having been obtained in continuous runs lasting for several weeks and representing thousands of tons of material. Strange to say what was considered impossible a few years ago, namely, the concentration of slimes by flotation processes, is now accomplished without any difficulty whatever.

The wonderful improvements in the reverberatory smelting of copper ores, to be mentioned below, have changed the ideas of millmen, so that coarse jigging will soon be abandoned, and nothing will be jigged coarser than $\frac{3}{8}$ of an inch size.

The material for flotation seems to concentrate better in proportion to the fineness to which it is ground. In many mills 60-mesh material is the coarsest that is sent to the flotation machines.

In roasting concentrates, the furnace of the McDougal type seems to have the preference. There are several styles of these furnaces on the market, and all seem to be giving good results.

Reverberatories Superseding Blast Furnaces

The introduction of oil fuel, followed a few years ago by the successful use of pulverized coal on reverberatory furnaces smelting roasted copper concentrates, has revolutionized reverberatory construction and practice. The latest furnaces are 25 ft. by 144 ft. inside dimensions and have a capacity of from 700 to 800 tons daily, with a fuel ratio of better than 7 to 1. A still larger furnace is now in course of construction that will measure 175 ft. by 25 ft. inside. This furnace is for the purpose of treating hot converter slags with raw copper concentrates in order to recover the copper in the slags and to make a slag clean enough to be thrown away. This furnace is estimated to have a capacity of over 1100 tons daily. Of course a greater part of the charge will be molten slag.

The fuel economies from the use of pulverized coal are astonishing. With a grate-fired furnace, and a similar furnace using the same coal in pulverized form, the fuel ration in the first case will be $4\frac{1}{4}$ to 1; and in the latter case, 7 to 1. The tonnage smelted by the pulverized fuel furnace is practically double that smelted by the grate-fired furnace. These economies will result in the relegation of the blast furnace (in a great many plants) to the smelting of extremely refractory ores, or it will cause their abandonment altogether, as the reverberatory furnace in most localities will be able to do the work at about 75 per cent of the cost of blast-furnace operation. Of course, there are some ores that it will be cheaper to treat in blast furnaces.

In blast-furnace practice the tendency is to enlarge the furnaces, and the types of furnace that may now be had give entire satisfaction, certain improvements having been introduced in recent years so that while the length of the furnace may be increased indefinitely, the size of the unit is not increased at all, as one part of the furnace may shut down for repairs while the rest of the same furnace may be kept in operation. The largest furnace at present in operation is 87 ft. long and 56 in. wide, inside measurements at the tuyeres. This furnace has smelted in 24 hours over 3300 tons of charge.

Basic-Lined Converting

In converting, the basic-lined converter is rapidly displacing the acid-lined shell, and the size of the converter is being increased proportionately to the capacity of the plant, up to a maximum of the vertical (or Great Falls) type of converter, of 20 ft. inside diameter. The vertical type of converter is preferred at most of the large smelters; the objection to the horizontal cylindrical type being the necessity for the numerous openings, in the larger converters, for the introduction of silicious material and the difficulty of getting uniform temperature, and agitation of the charge throughout the converter. In the 20-ft. vertical Great Falls type of converter there is no difficulty whatever in these matters. All new converters are operated electrically instead of hydraulically.

Another branch of copper metallurgy that is receiving a great deal of attention at present is hydrometallurgy, or leaching. Enormous plants are being constructed in various parts of the world to handle low-grade ores that are oxidized, or partly oxidized; and also to recover copper from old tailing dumps in which the copper has become oxidized.

Losses Minimized

Great attention is being paid to the recovery of valuable metals from fumes and from flue dust, and a modern plant must be equipped with apparatus for saving these metals. The Cottrell electrical precipitation apparatus seems to be the most suitable for copper-smelting operations; although with some ores, particularly those carrying zinc, the bag-house has been successfully introduced for this purpose, following the practice of lead metallurgists.

The economical handling of materials to and from the furnace is now brought nearly to perfection.

In conclusion the modern tendencies in copper metallurgy can be summed up in these words: Increased recovery in ore dressing: increased recovery of metals formerly lost in smoke and fume: reduced cost of operations, due to the introduction of larger smelting units and mechanical means of handling materials to and from furnaces: the introduction of pulverized coal as fuel for reverberatory smelting furnaces.

Anaconda, Mont.

Magnesium

The Aviation Materials Corporation has been incorporated under the laws of New York State to engage in the business of manufacturing metallic magnesium.

The corporation will operate under the patents of George O. Seward and F. von Kügelgen, the process having been developed by them at the Virginia plant of the Virginia Electrolytic Company.

Mr. George O. Seward, 99 Cedar street, New York City, is the president and general manager of the Aviation Materials Company. Work has been started on a plant to turn out ten tons of metallic magnesium monthly and the corporation expects to have the metal for sale inside of three months.

The **Joseph Dixon Crucible Company** of Jersey City, N. J., has just issued a new edition of the booklet "Dixon's Graphite Crucibles." In addition to a preface and the table of crucible sizes, information is furnished of steel melting crucibles, file crucibles, crucible covers, tilting furnace crucibles, retorts, bottom-pour crucibles, stirrers, skimmers, dippers and self-skimming crucibles. Some good advice is given in two pages entitled "For Oil Furnaces" and "General Hints" on the scalping of crucibles, use of fluxes and use of tongs. Foundry facings and a highly refractory cement for the repair of worn or cracked firebrick are also described.

Concentration by Crushing and Screening at the Vindicator Consolidated Mill

The new crushing and screening mill of the Vindicator Consolidated Gold Mining Company in the Cripple Creek district was put in operation Oct. 15, 1914. The object of the process employed is to increase the profit from the mine by treating the waste ore that formerly went to the dump. It is characteristic of many Cripple Creek ores that mechanical enrichment can be produced by simply crushing and screening, saving the finer and rejecting the coarser portions. This affords a simple method of concentration that will yield profitable smelting products from otherwise waste rock. The ultimate profit per ton is not great, but amounts to a considerable sum on a large daily tonnage. The cost of a mill is small compared with that of a concentrating and cyaniding mill such as is adapted to Cripple Creek ores, and the process probably can be applied to ores of too low grade to be treated profitably by the more elaborate process.

The former practice at the Vindicator was to sort the mine ore, shipping the first-class product to smelters and washing the waste in order to recover fine rich mineral adhering to the surfaces of the rock. The extent of the sorting process and the quantity of ore rejected from run-of-mine product is indicated in the last annual report of the company, wherein it is shown that of 76,295 tons of crude ore hoisted, 26,343 tons of shipping ore was sorted, leaving roundly 50,000 tons of waste rock to be thrown on the dump. The problem at the Vindicator was to devise a

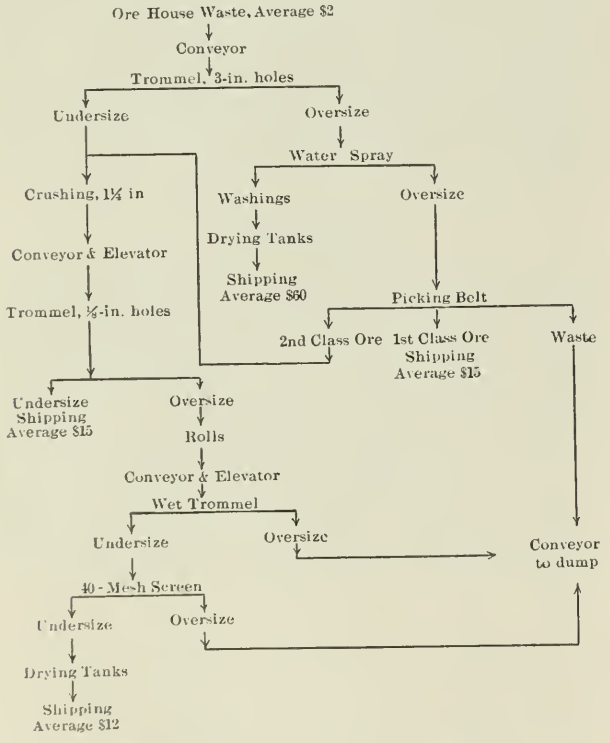


FIG. 1—FLOW SHEET VINDICATOR SCREENING MILL

profitable method of treating this ore-house waste, for the simple expedient of washing the waste and recovering fine mineral was not wholly satisfactory. Accordingly experiments were begun in 1913, under the direction of Mr. Edward S. Wiard, of Denver, to see what improvement could be made.

Preliminary Tests

Early tests indicated that the waste was capable of enrichment by crushing and screening. Experiments by jigging and tabling also showed good results, but not sufficiently high to warrant the consideration of such a process. The complete testing work involved many experiments in crushing, sorting, screening and washing,

FIG. 2—VINDICATOR SCREENING MILL

with separate assays of the various products. From these tests data were obtained showing quantities and values, and affording a basis for intelligent design of a mill. The plant as finally built cost roundly $34,000, and is reported to be treating about 400 tons daily.

The flow-sheet of the mill is given in Fig. 1, and a view of the plant in Fig. 2. The ore-house stands at the left of the mill in Fig. 1, being connected herewith by a conveyor that delivers waste rock from the picking-belt in the ore-house to a large trommel screen in the mill. The first section of the trommel screens out 3-in. rock and delivers it to the second-class ore bin. In the second section of the trommel the remaining rock receives a wash of water sprayed under 50 lb. pressure. The rich washings are delivered to settling tanks, and are shipped after drying. The trommel oversize is delivered onto a sorting-belt from which first-class shipping ore is easily picked by hand after the washing it has received. Second-class ore also is sorted and combined with the trommel undersize. The final waste from sorting falls onto a cross conveyor and is discharged to the dump.

The second-class ore is then crushed to 1¼-in. size and elevated to dry trommels fitted with ⅛-in. screen. The undersize of these trommels is a shipping product, and the oversize is retained for a second crushing in rolls to ⅜ in. The roll product is then washed in a wet trommel which serves merely as a scalping screen for the Bunker Hill 40-mesh screen which follows. The wet-trommel oversize is discarded, but the undersize is further screened on a Bunker Hill screen of 40-mesh, the oversize of which also is discarded. The undersize is a shipping product and is delivered to a settling tank and then dried. Thus the process comprises a preliminary wash, crushing in two stages with intermediate dry screening and final wet screening at ⅛ in., and 40-mesh, respectively. The values of the several concentrates are shown on the flow-sheet.

The arrangement of the plant is simple and convenient. The screens and picking-belt are placed in the top of the building, above bins and tanks which receive

the various products. All of the waste rock rejected from the picking-belt and screens is delivered to a common conveyor leading to the dump. The crusher and rolls are placed below their respective bins, and discharge their products onto conveyors leading to the two elevators that serve the dry and wet trommels.

The annual report of the company, dated Jan. 1, 1915, states that the new mill "has not been in operation at this time long enough to make any positive assertions, but the indications are that it will prove to be a very profitable investment." Judging from the care taken in the preliminary tests, the mill should add to the general profit of the company.

The Radium Situation

BY WARREN F. BLEECKER

The Standard Chemical Company of Pittsburgh was the first company with sound finances to seriously enter the radium business in the United States. Indeed there were scientific men in our own state, who, during the year in which this company was founded, seriously doubted that radium occurred in carnotite ores in commercial quantities, if at all. There were, in this country, no men who could determine radium quantitatively with any degree of accuracy and there were no metallurgical engineers trained in the treatment of the ores.

This is the problem, among others, Mr. Flannery has had to face, and how well he has done it the record of the last year has shown. Being a man of tireless energy, remarkable foresight and business ability, and associated with some of the best capitalists of this rich eastern country, Mr. Flannery carefully laid the foundation of a permanent business, the first of its kind in this country and the largest of its kind in the entire world.

The first step was the obtaining of property both by outright purchase and by location according to the laws of the land. As is well known, the Standard Chemical Company obtains its supply of raw ore from the south-western part of Colorado. When this company first came into the field the country was practically a wilderness; miles of roads were built, streams were bridged, homes were erected and employment furnished to hundreds of men and teams, thousands of dollars were expended monthly in salaries, wages and supplies. The problems of mining and transportation in this district are as great and no greater than in any other district of like isolation and remoteness from settled centers and supply bases. I do not mean, of course, that the Standard Chemical Company discovered radium in Colorado or that the country had never been entered by civilized man any more than a certain government official meant that he had discovered radium by having his photograph taken at the mouth of one of our tunnels, although the newspaper reports so stated. I wish to point out, however, that the real pioneer work of the development of radium mining, in the Paradox region, was done by private capital and that more than one million dollars had been expended in mines and processes before any cognizance or recognition of the work was taken up by the government.

After the development of mines, the building of roads and of camps, finally came the shipping of large quantities of raw ore, then of almost unknown value, to Pittsburgh. Then came the erection of the plant in which the experimental work was to be done. Following this was a long siege of costly experimental work; the training of engineers and scientists in the reduction of the ores, quantitative determinations of the values therein, the refining of the crude material into marketable products and the building up of a selling organization.

Any one who is familiar with the pitfalls which are confronted at every step in the building of a large business, using known methods, and producing standard materials, will at once realize what it has meant to found an establishment with unknown raw materials, untried processes for treating them, and with no market demand for the products.

Radium itself, considered in the light of its weight in pounds and ounces only, is a metal of almost fabulous value. When it is seen that it may be necessary to treat 1 ton of ore to obtain 1 mg of radium, it will be seen that the metallurgist is removing one part of material which he can never see, feel, or recognize by any of his natural senses, from one billion parts of foreign matter. Further, this one part must not be lost although it is carried through a maze of chemical reactions, in expensive and sometimes fragile apparatus, until it is relatively pure and ready for refining. When it is further realized that the loss of one drop of liquid, under some conditions, would result in the loss of several hundred dollars worth of radium, some conception may be had of the difficulties involved in removing this element from the raw ore and its subsequent refinement.

During the last two years, certain persons have prevailed upon a branch of the national government to assist them in entering the radium business, not in competition with, but to the ultimate exclusion of, the producers now in the field. So far as the general public know, this is purely a government enterprise. My understanding is that it is not purely a government enterprise, but an arrangement on the part of private individuals, for government backing, in order to obtain a monopoly of the radium business. This is not a logical proposition because the production of radium does not differ, *per se*, from the production of steel, copper or gold.

We should be justly alarmed should the government take over our smelters, refineries and reduction works; but we would indeed have further cause for unrest should the national government, in addition to taking over these things, put them in the hands of certain favored private individuals—under any working agreement —for a division of the spoils. While the legality of this procedure is very doubtful, we may be quite sure that it is without precedent in the history of our country.

It is a fundamental law of business that any enterprise is hazardous if the supply of raw material is limited. The hazard is greatly increased if the supply of raw materials is entirely shut off. As we all know, a mine is a mine; every pound of material removed from it makes the mine capable of producing so much less— it is not an inexhaustible storehouse of wealth. Therefore, when our mines are worked out we must look for others, and if they cannot be obtained we must go out of business. This applies to any industry which is engaged in the reduction and refining of materials taken from the surface of the earth. The government proposes to limit our raw material to that which we already have and, in this way, has set the date for our retirement just as definitely as if they had given us so many days or months to operate.

It has been stated that the Standard Chemical Company now controls or is trying to control the radium industry by acquiring all of the radium deposits. Were it not that the past few decades have seen the growth of trusts and monopolies, and that the people as a whole are prone to believe an accusation of this sort, thrown broadcast by any and all persons, responsible or irresponsible, it would be idle to mention this subject. As a matter of truth, the Standard Chemical Company now owns and controls less than one-half of one per cent of the known radium deposits in the section in which they are operating.

This is not a matter which effects merely the Standard Chemical Company or my personal interests in the matter; it effects not only the development of the state of Colorado, which unfortunately has suffered too much already by outside interference in her affairs, but further than this, it is a matter of national and international importance. To Colorado one must look for the world's supply of radium, and if properly conserved, there is enough to supply the world. If, on the other hand, the ores are withheld or their values are wasted by crude and improper methods of treatment, whatever value radium may have will be lost and this generation at least will derive no benefit therefrom.

Assuming that the government intends to enter the radium field, seriously, there are several practical problems which will be apparent to sensible people and which are of fundamental importance.

In order to produce radium, one must have mines. These the national government can easily obtain either by withholding undeveloped lands or by confiscation. Then the mines must be worked under the direction of competent engineers. In order to mine efficiently, one must do it scientifically; scientific mining requires training and skill. Trained mining engineers are, as a rule, men who command good salaries for their labor. No one has ever complained, I believe, of government scientists being over-paid. Those who propose that the government can produce radium without mining it as well make a virtual acknowledgment of business incompetency, because the business is hazardous enough when one is assured of his supply of raw material.

I do not mean by this to cast reflection upon the scientific investigations made by government men in this or any other research which they have undertaken or may undertake. The business men, however, are compelled to recognize the difference between men of purely scientific attainments however profound, and the application of these things to a bank account. Scientific research is one thing and operation is another.

The problem that the national government would face in reducing carnotite ores is no greater nor is it less than that faced by a private individual or corporation. Be it said that the working out of this problem requires a faith without limit, business management of the highest degree, and sufficient reserve funds, to carry the experimental work over and through many dark and stony places.

It is a human failing, that the things we know the least about appear to be done with the greatest ease. It is not surprising, therefore, that private individuals, or government officials, should regard the reduction of carnotite ores as a problem quite on a par with the reduction of other ores of a seemingly similar refractory nature. The chemical reactions of the various elements which constitute carnotite ore are known to a limited extent, but the relations of these elements in the ore, and the difficulty of maintaining economical methods of chemical separation, present unusual difficulties which are not overcome so easily as might be expected.

The Austrian government has for some years been in the radium business. The ores available for their use are the richest which can be found or which can be hoped for. With this tremendous advantage, which America can never hope to have, the price, even with such improvements in their processes as the Austrian scientists have been able to devise, has gone up in that country instead of down. Further than this, any one who has attempted to purchase radium from the laboratories of the Austrian government have suffered delays of many months because of the exceedingly slow rate at which the radium is being produced.

Should I be in error as to what the government has already done, in the treatment of carnotite ore, it is due to the fact that their work has been carried on under a veil of secrecy and mystery. It was stated, however, (I am willing to be corrected on this and other points in which I may be in error) that about one year ago, there was available for the so-called government plant in Denver a quantity of ore of about 1000 tons containing about 9 grams of hydrous radium bromide. What was to be done with this radium after its extraction, I have no positive knowledge excepting that there were reports that it was to be divided between government and certain private individuals. It was also stated that the government process, for the extraction of the radium of this ore, had passed the experimental stage some time during the winter or spring of last year. I do not know the proposed rate at which this ore was to be treated but have heard that it was to be of 5 tons per day.

Recently the radium produced during the year's operation was introduced at a hearing before the Congressional Committee in Washington, D. C. The quantity of radium was stated to be 170 mg; this, however, was on the basis of hydrous radium bromide and the radium content would therefore be 53 per cent of this or 90 mg of radium element. It was stated that this radium had been produced from the treatment of 220 tons of the ore mentioned above, in addition to some 1900 lb. of exceptionally high-grade ore which had been purchased quite recently. Assuming that this 220 tons of ore treated was not selected as the poorest ore that could be obtained, it would contain, on the basis of 9 mg of hydrous radium bromide per ton, 1980 mg. Nineteen hundred pounds of 30 per cent ore should contain about 116 mg of radium bromide. Therefore, there seems to have been extracted 170 mg out of 2096. The efficiency of this process is, therefore, 8.6 per cent. No organization in the world, excepting a government organization could afford to operate a plant with an efficiency of 8 per cent.

The Bureau of Mines of the United States Government has endeavored to secure the passage of legislation which will withdraw carnotite lands and prevent the location of the same by private individuals, excepting under certain restricted if not prohibitory conditions. The reason given for this is stated to be that the Bureau of Mines, under this favorable condition of monopoly, may produce and manufacture radium for government hospitals. Those familiar with the matter at the present time, must surely be aware that this radium can now be bought at a price cheaper than that at which the government can produce it.

By promising to produce radium at one-third the present market price, a great injustice is done, not only to those who are producing radium, but especially to those expecting to receive relief from the application of radium as a curative agent. A person suffering with cancer, for example, cannot, as a rule, buy radium. Even if he possessed it he could not safely apply it to his ailment.

The medical profession and scientists who are at the present time willing to purchase radium for the treatment of disease and for investigation, are misled by promises of obtaining the radium at a greatly reduced price in the near future.

Without questioning the good faith of the persons who have made and widely advertised such statements at the present time their promise has not been fulfilled. Whether it ever will be fulfilled may be said to be a matter of opinion and for the future to tell. Personally —and I think I am entitled to speak with authority on the subject—I do not think the promise can be fulfilled.

The net result so far has been the discouragement of

investigation and the denial of this curative agent to those who need it. Again, purely as a matter of opinion, I am convinced that this procedure is morally wrong.

Under the present unsettled conditions it is doubtful if not improbable that any group of capitalists would care to risk any money whatsoever in developing the radium industry. And it is certain that should the present plans bear fruit, the radium industry will be absolutely a closed book so far as private enterprise is concerned. Prospecting, mining and development work will be greatly curtailed until those who have promised to produce radium at a greatly decreased cost, are able to make good and show their willingness to distribute their product among those who need it. The investigation among scientific men and institutions will be limited to those who already have a supply of radium because no one is going to buy any material which he believes can be procured, a short time hence, at one-third the market price.

So far as I can ascertain, the promise that radium will be produced at a much lower price, does not carry with it a guarantee that the ultimate buyer will get it at any price whatsoever. The agreement between the government and private parties is, as I understand it, the first 7 grams are to be retained by one man or set of men. At the present rate of 170 mg a year, one must arrive at the conclusion that it will be years before cheap radium will be distributed among physicians and scientists at large.

To those who may have been misled by more or less recent statements, that the ores now mined in Colorado are for the most part exported and thereby lost to our home people, it may be said that the small amount of ore which was mined by prospectors, up to the time the Standard Chemical Company began operation, was sent to Europe. Since that time, as a matter of record, at least 85 per cent of the carnotite ore mined in southwestern Colorado has found its way to Pennsylvania for treatment. In 1913 the exact figure was 83 per cent. The percentage was much greater than this in 1914. It would only be justice to the capitalists and engineers who have put their energies into the solving of this problem to state that the Standard Chemical Company is now producing four-fifths of the world's supply of radium. No mention has been made, I believe, in the Bureau of Mines' publications as to the magnitude, either actual or relative, of this strictly American enterprise.

In the future the radium business will be successful only under one condition—and that is large tonnage. It will always be impossible to maintain an efficient organization of engineers and scientists unless the tonnage is sufficient to pay their salaries.

Standard Chemical Co.,
Canonsburg, Pa.

Heat Insulation.—Heat insulation is as important in refrigerating plants as in boiler plants. In boiler and steam lines the struggle is to keep the heat inside where it belongs. In brine and ammonia lines, in the freezing tank and the cold storage rooms, the struggle is to keep the heat out. Under the suggestive title "Permanent Fortifications" the Armstrong Cork & Insulation Company of Pittsburgh, Pa., has just issued an interesting little bulletin in which illustrations and cost data are given from actual practice showing what can be done in the way of heat insulation by means of the company's nonpareil corkboard, insulating brick and high-pressure covering. Nonpareil high-pressure covering is made of diatomaceous earth and asbestos. It contains no cork whatever. For steam lines, it affords a permanent fortification against heat loss. It is not only an excellent heat insulator, it is also proof against water and steam.

Court of Appeals Decision in the Pyrophoric Alloy Suit

In our issue of April, 1914 (Vol. XII, p. 218), we published the decision of the District Court of the United States, Southern District of New York, in the suit of the Treibacher Chemische Werke versus The Roessler & Hasslacher Chemical Company. The decision was in favor of the complainant, the Welsbach patent in question being held to be valid as a pioneer patent and to have been infringed.

The U. S. Circuit Court of Appeals, Second Circuit (Judges Lacombe, Ward, and Rogers), has recently confirmed this decision. Mr. James Hamilton was counsel for the Treibacher Chemische Werke which won out.

The decision of the Court of Appeals is written by Judge Lacombe. In view of its importance with respect to the legal doctrine of equivalents we give the decision in full:

"The invention relates to manufacture of metallic alloys having pyrophoric action and their application to the purposes of ignition and illumination. The alloy gives forth sparks on being rubbed with a file or otherwise abraded—hence the term 'pyrophoric'. The substance is of conceded commercial utility. Being an alloy it is a compound of two or more metals. Out of fifty-five or more known and classified metals, sixteen are recognized as 'rare-earth metals'; these sixteen are divided into three groups, the cerium group, the terbium group and the ytterbium group. One of the metals in the alloy of the patent must be a rare-earth metal, and by the language of his specifications the patentee states that for the purposes of this invention the presence of the cerium is relied on as essential.

"Therefore, although there may be a mixture of rare-earth metals in the one element of the combination, cerium, or at least a metal of the cerium group, must be present. The testimony shows that an alloy composed solely of rare-earth metals will not produce the pyrophoric alloy desired; the patent indicates this. The presence of one or more of the non-rare-earth metals is essential. The specification states that the rare-earth metal cerium becomes pyrophoric if alloyed with certain other metals, in particular iron. It indicates that with about 30 per cent of iron the alloy attains its maximum of pyrophoric energy; also that the iron can be partially replaced by nickel or cobalt, but if entirely replaced by these the pyrophoric property is considerably diminished.

"The first claim reads: '1. A pyrophoric alloy, containing cerium alloyed with iron; substantially as and for the purposes described.'

"The only other claim is identical except that the iron is stated as being 30 per cent of the compound. As defendant's compound consists of cerium with from 11 to 15 per cent of magnesium, the first claim only is declared upon.

"Judge Hough, discussing the most pertinent references in the prior art, found that the patentee 'taught how certainly and knowingly to produce that' (a compound usefully pyrophoric) 'which had been observed indeed, but not understood.'

"We fully concur in this finding and in the conclusion that this Welsbach patent covers a pioneer invention and is entitled to that liberal application of the doctrine of equivalents which is usually accorded to such patents.

"In defense it is contended that defendant's product, made it is said according to the process set forth in a patent to Huber (No. 967,775, issued August 16, 1910), is not a 'metallic alloy' at all, but a chemical compound. What defendant does is first to make a metallic alloy of cerium and magnesium (in the proportions of about eighty-five to fifteen); this alloy is then subjected to the action of hydrogen in a fire-clay muffle under a temperature of 500 deg. to 600 deg. C. Changes are produced by this hydrogen treatment—the pyrophoric property of the compound is improved, possibly sufficiently to give validity to the Huber patent—and there is a conflict between the experts as to whether the resultant product has become a chemical compound or still remains a metallic alloy saturated with hydrogen. We concur in Judge Hough's finding that the weight of testimony supports the latter conclusion.

"The claim in suit mentions only iron as the non rare-earth metal, but multitudinous authorities support the proposition that, in construing a pioneer patent such as this, 'iron' should be held to mean 'iron or its equivalent'. In the specifications two other metals, nickel and cobalt, are expressly referred to as equivalents and defendant conceded

that a metallic alloy in which these, or even manganese, which like the other three belongs to a group known as the 'heavy' metals, have been substituted for the iron, would infringe.

"But the doctrine of equivalents does not confine a patentee to equivalents which he has expressly referred to. Numerous authorities sustain the proposition that when, as here, a pioneer patentee claims an alloy of one or more rare-earth metals with one or more non-rare-earths metals, he is not restricted to named varieties of either, unless he has himself restricted his claim by something in his specification, as Welsbach did, on the rare-earth side of the combination by the statement that in his alloy cerium is an essential (Winans v. Denmead, 15 How., 330). Welsbach nowhere intimates that iron is essential, on the contrary he stated his invention is the alloy of cerium 'with certain other metals, in particular iron.'

"We are satisfied that the 'equivalency' of other metals with iron is to be found not in their chemical structure, but in their functional efficiency when combined with cerium in a metallic alloy.

"Cases in this circuit (Mattheson v. Campbell, 78 F. R., 910; Richards v. Du Bon, 97 F. R., 96; Panz v. Battle Island Paper Company, 138 F. R., 48) have indicated a qualification of this theory of broad equivalents—a patentee will not be allowed to maintain a claim for more than he has discovered and disclosed. In the first of these cases the claim was for a dyestuff as a new product. The patentee described a special process by which the product was obtained, using therein a specified sulfo-acid; he stated as his discovery, invention and disclosure that 'any sulfo acid of any radical', when treated according to the process described, would produce the dyestuff of the patent. The testimony showed that there were over 100 different substances in the group of 'sulfo acids of any radical' and that only some of them—disulfo-acids, with which along the patentee had experimented—would, when treated according to the process, produce the dyestuff. The complainant contended that whenever a particular sulfo-acid, not tried before, produced the dyestuff his patent would cover it, although it did not cover sulfo-acids, which would not produce the result. We held that he could not thus 'speculate on the equivalents of his claimed invention and thereby oblige the public to resort to experiment in order to determine the scope of the claim of his patent.'

"In the second case above cited the claim was for an improvement in the art of treating tobacco leaves which consisted in 'applying an alkali to the leaves of the growing plant.' Patentee had produced his result of applying a specified alkali to the leaves, but the broad construction of the claim covering *all* alkalis was held void because it would be broader than the invention, as it would cover potash, an alkali which would not accomplish the result, and the patentee had not experimented to discover what alkalis would and what would not do so.

"The case at bar, however, does not come within the principle laid down in these decisions. Of the forty or more non-rare-earth metals it is now shown that there is one of them which will not when alloyed with cerium produce a pyrophoric compound. Some of them will produce a less efficient one than iron does, as the patent indicates, proportions must be varied with different constituents to produce better results, but we are satisfied from the record that (with the exception of metals found in such small quantities that they are known merely in the laboratory and so no one has experimented in combinating them with cerium), each and every non-rare-earth metal is a fair equivalent of iron in the compound of this patent.

"The decree is affirmed with costs."

We comment on the scope of the decision in our editorial columns.

The production of radium, uranium and vanadium in the United States in 1914 was the largest in the history of the country, according to the U. S. Geological Survey. The output amounted to about 4300 tons of ore carrying 87 tons of uranium oxide and 22.4 grams of metallic radium. A little more than 1200 tons of ore containing 28.1 tons of uranium oxide and 7.2 grams of radium, was consigned to Europe; but owing to the war some of it was held in transit. The Standard Chemical Co. and the Radium Company of America produced radium salts during the year, but with the opening of the war nearly all operations were stopped, both at mines and mills. The National Radium Institute, Denver, is now in operation under Bureau of Mines officials, and is producing radium salts.

The Non-Ferrous Metal Market

The month intervening since our last report has witnessed some striking changes in metal prices, the upward trend being most marked in the case of spelter. Copper, tin and lead also experienced a rise culminating during the first few days of Febraury, after which prices receded somewhat. Export demand for spelter, copper and lead has been in evidence and, added to domestic needs, has given the markets a firm tone.

Copper.—During the first three days of February electrolytic copper reached a high price of 14.55@14.60 cents, New York. Since that time the price has fallen off a little to about 14.10@14.20 cents. Business also has slackened and the market is dull.

Tin.—This market reached its high price on February 2, when the New York quotation was 38 cents per lb. Since then it has receded to 36. The rise was without apparent reason, and was regarded as unwarranted.

Lead.—The New York market has been set by the A. S. & R. Co. at 3.80 cents per pound. The St. Louis market has been higher than the usual parity, being quoted at 3.65@3.70 cents. The market is firm though transactions are not on a large scale.

Spelter.—Stocks of this metal, including February production, have been sold out, and considerable business has been done for April and March delivery. Prices have advanced by leaps and bounds, and the high figure may not yet have been reached. New York quotes 7.80@8.30 cents, and St. Louis 8.12½.

Other Metals.—Aluminium is in better demand and the market is stronger at 19@19½ cents, New York. The antimony market is active and large sales are reported both for export and domestic use. Prices range from 17 to 21 cents per lb. Quicksilver has shown an upward tendency, the New York price being $54@$57 per flask of 75 lb. San Francisco quotes $55 per flask.

Mellon Institute of Industrial Research

The new beautiful building of the Mellon Institute of Industrial Research, University of Pittsburgh, will be opened on Friday, February 26, 1915. There will be a reception by the trustees and director in the evening. Professor John J. Abel, of Johns Hopkins University, will deliver the first Mellon lecture under the auspices of the Society for Biological Research of the University of Pittsburgh in the lecture hall of the Mellon Institute on the evening of Saturday, February 27.

The new building which was erected at a cost of $350,000, is the gift of Messrs. A. W. and R. B. Mellon, of Pittsburgh.

The Mellon Institute of Industrial Research stands a monument to the life work of the late Robert Kennedy Duncan. Dr. Raymond Foss Bacon is the director of the Mellon Institute.

The production of manganese ore in the United States in 1914 probably did not exceed, if it equalled, that for 1913 when 4048 tons was the output. Imports have been seriously affected by the war, and during the first nine months of 1914 amounted to only 42,550 tons, or 16 per cent less than for the corresponding period of 1913. Ferromanganese also has fallen off in imports to the extent of 37 per cent, amounting to only 37,420 tons during the first nine months. Three-fourths of our imports have come from Russia and India, and the Russian product has been cut off by reason of the closing of the Bosphorus by the entrance of Turkey into the war. The effect of the shortage in the United States has stimulated interest in domestic deposits, but no important new discoveries have been made.

A Classification of High-Temperature Physical Problems

BY EDWIN F. NORTHRUP

We may assume that temperatures may be produced, artifically, ranging from 2 deg. K. to 4000 deg. K. It is not at all improbable that a temperature exceeding 4000 deg. K. may be produced by electrical means combined with high pressure. But as these methods have not as yet been developed we shall assume that 4000 deg. K. expresses at present the upper limit of temperature producible in the laboratory.

The temperature above which temperatures shall be called "high" or below which they shall be called "low" is very largely arbitrary. In order, however, that definiteness may attach to what follows we shall divide the range of producible temperature into four groups as follows:

Low temperatures... .....0° K. to 233 K. (−273° C. to −40° C.)
Ordinary temperatures.....233° K. to 373° K. (−40° C to 100° C.)
Medium temperatures....373° K. to 1273° K. (100° C. to 1000° C.)
High temperatures....1273° K. to 4000° K. (1000° C. to 3727° C.)

Until within recent years most scientific investigation, with the exception of the study of certain radiation phenomena, has been confined to the range of ordinary temperatures. An examination of the physical and chemical constants, hitherto listed, shows how little the properties of matter outside this range have been studied. This is probably explained by two considerations; first, the means and the apparatus for investigation of the properties of matter below and above ordinary temperatures were undeveloped, and second, information acquired concerning phenomena, only exhibited by matter outside the temperature range in which contact with matter is had in the ordinary affairs of life, formerly possessed, like astrophysics, only an interest purely scientific. Industrial processes were not then, as now, very much dependent upon exact information respecting the laws and properties of matter when outside the range of ordinary temperatures.

The science of the past was engaged in detecting the invariable relations which exist between phenomena when conditions are repeated, in explaining the seeming chaos of nature by codifying the invariable relations of force manifestations, and in discovering and explaining phenomena at ordinary temperatures. This task was made vastly more difficult by the circumstance that in the range of ordinary temperature nature is manifested in her greatest complexity. More phenomena are presented to our senses at ordinary temperatures, and at these temperatures there undoubtedly exist vastly more abundant physical, chemical and life phenomena than in the lower and higher temperature ranges. The growth of our body of science had to take place in a temperature range where the complexity of phenomena was such as to make them most difficult to interpret.

Very low and very high temperature investigations are relatively simple. By passing to the high temperature range we at once eliminate from consideration all such phenomena, as crystallization, magnetism, surface coloring, production of aqueous solutions, the greater part of the phenomena of organic chemistry and a multitude of other familiar physical and chemical manifestations. The science of biology outside the range of ordinary temperatures is non-existent.

As the means and apparatus are now available for quantitative investigation in the lower and higher temperature ranges, a rapid progress should be made in the discovery and interpretation of the phenomena persistent in these ranges, because they are relatively so simple. When nature is studied, simplified, so to speak, we should be able to acquire a better understanding of the increasingly complex phenomena which appear as we bring the lower temperature range up and the higher temperature range down. In the light of our knowledge of nature simplified we shall be better able to interpret her more complex manifestations at ordinary temperatures.

By this new method of scientific investigation at extremes of temperature where nature is relatively easy of interpretation we see before us a line of attack leading to a vast territory of new knowledge. Consider as a concrete case the advance in our understanding of metallic conduction by the work of Onnes at low temperatures. He finds the conductivity, presumably by the atoms being in contact, to be infinite. Again, when others examine at high temperature the metals in their fluid state, their laws of conduction are studied free from the complexities produced by crystallization and past physical history. The temperature-resistance curves of most of them are expressed by straight lines, and, in the main, the resistance is found to get greater as the atoms become more separated by the heat expansion. How much more difficult it would be to arrive at a knowledge of the nature of metallic conduction if we confined ourselves to its study where metals are by chance hard or soft, crystallized or uncrystallized.

The study of matter at *low temperatures* has scientific interest chiefly because it leads to a better knowledge of matter at ordinary temperatures. The knowledge of the laws of matter, physical and chemical, at low temperature does not, however, appear to promise much industrially. This is chiefly due to the fact that the industrial use of temperature, outside the range of ordinary temperatures, has been to bring about new chemical equilibria which remain stable when the product is returned to ordinary temperature. By means of high temperature we produce new chemical products which are stable, and hence useful, at ordinary temperatures. At low temperature, on the other hand, new chemical equilibria are not established and matter taken from ordinary temperature to a very low temperature and again returned to ordinary temperature is, in general, unaltered in its chemical constitution. The new physical aspects assumed by matter at low temperature also, in general, disappear when the temperature is again raised, and the new physical states which exist only at low temperatures have so far, at least, found very little use in the industries.

To those who feel an interest in science chiefly because it gives an understanding of the laws and properties of matter which can be industrially utilized, high-temperature investigations will appeal with more force than low-temperature investigations. The low-temperature range has its able and enthusiastic devotees, but our interest lies in the high-temperature range. The question then presents itself to us: What kinds of investigation at high temperature are possible and useful? To help answer this question we give a classified list of high-temperature problems as these present themselves to our mind. With this list for a guide we shall be in better position to select for investigation problems which experience and judgment indicate are scientifically interesting, industrially useful or both.

High-Temperature Problems

In classifying these the high-temperature range is arbitrarily selected to lie between 1000° C. and the vaporization temperature, at atmospheric pressure, of pure graphite. In what follows respecting the production of temperature only temperatures which are producible by electrical means are considered.

In high-temperature investigation, where all life phenomena are absent, all problems for consideration are included under the general heads: Physical Prob-

lems, Chemical Problems, Electronic or Thermionic Problems and problems in the practical production and measurement of high temperature.

A mere enumeration with occasional comments on all the problems which suggest themselves which are covered by the above four headings would make an article of greater length than is here intended, and only the *physical problems* which suggest themselves are enumerated at this time.

High-Temperature Physical Problems

The physical forces and properties of matter presumably manifested at high temperature and which await investigation are in part included in the list below:

1—*Gravitational Attraction of Matter.*—Is the experimental proof complete, that the gravitational attraction of matter is entirely unchanged when the temperature is raised to the neighborhood of 4000° K.? This is a somewhat difficult but an extremely important question to answer definitely. It is probable that the requisite temperature could be obtained by a chemical reaction, as by thermit.

2—*Surface Tension.*—Does it belong to all matter in the molten state? How does its value in the case of molten metals change with increase in temperature? Is it due to a gravitational, electrical, chemical, or to an un-named force of attraction between molecules or atoms? Surface tension of molten metals could probably be investigated by taking instantaneous photographs of falling globules of the metal and observing the vibration period of the globules.

3—*Molecular Cohesion.*—What are the laws of alteration (or weakening) of molecular cohesion of the highly refractory solid elements and certain of their useful alloys, etc. with great increase in temperature? This is the problem of finding suitable materials for high-speed cutting tools which may be run red hot, and of the tensile strength of wires and cables which must be used under conditions of high temperature. How do the highly refractory metals, W, Mo, and Ta, etc., preserve their elastic properties at high temperature? Is the internal molecular friction increased or lessened at high temperature in materials of this class?

4—*Molecular Adhesion.*—What metals, when in the molten or vapor states, will adhere to or "wet" certain other higher melting point metals in the solid state? Thus, gold wets molybdenum, tin does not wet tungsten. Do metallic liquids or vapors ever wet non-metallic materials? What are the facts and laws regarding the metallic coating of surfaces at medium or high temperatures without the use of aqueous solutions? Inquiries in this line would appear to have commercial importance.

5—*Forces Which Cause Materials to go Into Solution.*—How are materials related as solvents and solutes at various high temperatures? Thus molten copper dissolves copper oxide and also nickel. It does not dissolve molybdenum or tungsten. Why? What are the characteristics or properties of a material or element which which determine its solubility at high temperature in a molten element? This problem is the immense one concerning the formation of alloys and the segregations which occur when the temperature is lowered.

6—*Thermal Expansive Forces.*—What are the curves of volume versus temperature of materials, especially the non-gaseous elements when in the molten or vaporous states? Do liquid metals increase in volume proportionally to the temperature and does their increase in volume maintain the same ratio to their increase in some other physical property, as their electrical resistance? Is there any case where the second property can be deduced from a knowledge of the first? Do the vapors of the easily vaporizable metals obey the ordinary gas laws, as Boyle's law? Will a knowledge of the laws of expansion of molten metals of high vaporization point, as tin, enable the property of expansion to be conveniently used for the accurate measurement of very high temperature?

7—*Specific Heat.*—The specific heat of nearly all substances which are non-gaseous at very high temperature await precise determination. Thus, if the specific heat of tungsten or molybdenum were accurately known up to their melting points an excellent calorimetric method of measuring very high temperature would appear to be easy to develop.

8—*Vapor Tension and Boiling Points.*—The vapor-tension curves of practically all materials, which are solid or liquid in the high-temperature range, await determination. Some of the molten metals, as gold, show considerable evaporation at temperatures considerably under their boiling point, while others, as copper and tin, show comparatively little evaporation until near their boiling point. An accurate determination of the boiling points at atmospheric pressure of most of the metals is much needed. There appear to be good reasons for supposing that accurate determinations of the boiling points of several of the pure metals in the high-temperature range, would furnish a series of "fixed points" of high temperature which would be very useful for calibration purposes.

9—*Fusion Temperatures.*—An accurate determination of the fusion points of many of the pure metals has already been made, but much remains to be done respecting fusion points of the highly refractory metals and certain of the salts. It is especially desirable to determine how the fusion temperature of several of the metals, especially of the precious metals, is influenced by the nature of the vapor or gas in which the fusion of the metal takes place. Thus the fusion temperature of the platinum and platinum rhodium used in thermocouples is much lower in a Co+N atmosphere than in an oxidizing atmosphere. In what atmospheres are the fusion points of the various metals normal and how and to what extent are they affected by other atmospheres?

10—*Viscosities.*—Practically nothing is known in a quantitative way respecting the viscosities of molten salts and molten metals in the high-temperature range. Thus, pure molten iron is said to be quite viscid while pure molten copper is extremely limpid. The velocity of flow of molten metals and molten lavas, etc., largely depend upon the viscosity of the materials.

11—*Compressibility.*—The compressibility of many elements and inorganic compounds with application of pressure and high temperature, is a geophysical as well as a physical problem of importance. This line of investigation is being followed by the Geophysical Laboratory, at Washington. A successful attack upon the problem involves the ability to produce a localized high temperature in the zone of compression and to maintain the surrounding zones cool to permit the compression cylinders to maintain their mechanical strength. All matter at a great depth below the earth's surface is presumably at high temperature and under great pressure. Hence experimental information upon the compressibility of matter at a high temperature gives information regarding the state of the earth's interior. Experiments should begin with a study of the compressibility of the metallic elements when at a high temperature. The resistivities of the metallic elements should be simultaneously studied as undoubtedly there is a close connection between the resistivities of the metals and the closeness of the packing of their atoms or atomic groups.

Query: Is it experimentally possible to bring certain metallic vapors to the condition of being at the critical temperature and at the critical pressure?

12—*Elasticity.*—How is the elasticity, or the ability to maintain or prolong vibration, related to temperature, in the case of those metals and alloys which only fuse at a high temperature? How is the logarithmic decrement of a tungsten wire subjected to rotational vibration related to temperature in the region of high temperature? Or how is its elastic fatigue affected by high temperature? Can all "physical past history" be wiped out by application of high temperature in the case of a material which is not fused by the high temperature? Will increase of temperature which increases molecular separation with a related increase in electrical resistance, in the case of most metals, diminish or increase internal molecular friction? Thus Prof. Malcolm MacLaren has shown experimentally that elevation of temperature greatly reduces magnetic hysteresis. Should we therefore expect that a tuning fork of tungsten would continue to vibrate longer above 1000° C. than it would under this temperature? The experiment could easily be tried for the torsional vibration of tungsten, molybdenum and tantalum wires.

13—*Thermal Conductivity.*—The study of thermal conductivity at high temperature is an extensive field. The inquiry should extend to the relations which thermal conductivity bears to electrical conductivity in the case of elements and alloys. Is there a sudden transition, increase or decrease, as there is in the case of electrical conductivity when a metal changes state? A method has been devised and a piece of apparatus constructed, by the writer, for answering this question.

The investigation of thermal conductivities at high temperatures of inorganic compounds and refractories has a high value for engineers engaged in the construction of high-temperature furnaces. Will these investigations answer the query, whether the transport of heat by conduction is entirely a phenomenon of the passing along of molecular vibrations, or is it due in part or wholly to agitations brought about and passed along by the bombardment of molecules with electrons?

The thermal conductivity of powders determined as a function of their compression should be examined. Even metallic powders when fine grained, as powdered molybdenum, for example, show a high electrical resistance when not under compression and a fairly low resistance when under compression. Is there an analogous relation for the thermal resistance? On account of surface thermal resistance it is probable, that very high thermal insulation might be obtained by concentric metallic cylinders of very thin metal with very small separation between the layers. What would be the thermal conductivity of a stack of alternate layers of thin tin-foil and tissue paper? The writer knows of no data on this subject.

14—*Cooling Curves.*—The determination of cooling curves of the metals, and especially of the alloys, and the relations which they bear to the resistivity curves, is a highly important line of investigation. If the resistivity curves of metals and alloys are definitely related (as there are reasons to suppose they are) to the cooling curves, it is important to determine these relations precisely on account of the light which this information would shed upon the nature of metallic conduction, and because of the practical value to be derived in studying the physical properties of alloys, by determining their resistivities curves by the very simple methods which the writer has devised.

15—*Radiation.*—The radiation from hot bodies offers the most unlimited field of investigation at high temperatures. In addition to the many problems in optical pyrometry, in the study of spectral lines, in the motions of stellar bodies determined by the shifting of their spectral lines, in addition to the problems of absorption of spectral lines by metallic vapors, and the whole question of the synchronism of molecular and atomic vibrations with ether radiations of definite wave lengths, there are a few less commonly stated problems:

(*a*)—What are the laws of metallic reflection from the bright surface of molten metals? Thus the surface of copper at 1600° C. in a reducing atmosphere makes an excellent mirror and gives an image of objects which receive their illumination from the surface of the mirror itself. Is the light in this case polarized at any angle? What in general are the laws of the phenomena?

(*b*)—Do molten salts at very high temperature, which are known to be good conductors of electricity, retain their optical transparency? If they are optically transparent how does their electrical conductivity vary with the frequency when alternating current is used? What is the list of materials which are transparent above 1000° C.? The writer has thought out a method by which this determination could be affected.

(*c*)—As the temperature of a metallic vapor is gradually elevated to near 3700° C. will new spectral lines appear with sufficient suddenness, or will existing lines change in character, so as to permit the temperature to be measured with a direct vision spectroscope? The "cascade attachment" of the Northrup high-temperature furnace offers a perfect means for investigation along many lines of high-temperature radiation.

(*d*)—What are the indices of refraction of molten salts where these are transparent?

(*e*)—What are the coefficients of absorption for light of different wave lengths of the metallic vapors? Much could be learned regarding the vibration frequencies of metallic atoms by the study of the light absorption of metallic vapors.

16—*Osmotic Pressure.*—Can a porous diaphragm be found which molten salts will "wet" at a high temperature? If so, may it not be possible to observe at high temperature the phenomenon of osmotic pressure with molten salts? It is well known that molybdenum is wetted by certain metals, as molten copper and molten aluminium. Could not a diaphragm be made of strongly compressed molybdenum powder and by using this diaphragm to separate an alloy, of say tin and copper on one side and pure tin on the other, to produce the phenomenon of metallic transfusion and metallic osmotic pressure?

17—*Radioactivity.*—Has it been finally and definitely proved that excessively high temperature will not induce either a state of radioactivity or new radiations analogous to X-rays?

18—*Solubility of Gases in Molten and Solid Metals.*—Will a bulb of more or less porous material entirely submerged in a molten metal, as tin above 1000° C., form a gas-tight vessel? What is the solubility, if any, in the different molten metals at high temperature of various kinds of gases? Tungsten and molybdenum heated in a CO+N atmosphere always become crystalline and brittle. Is this due to an absorption and chemical combination with the CO gas? The properties of most metals are much modified when heated in various atmospheres to a high temperature but practically no definite data are available, respecting just what occurs.

19—*Solubility of Metals in Fused Salts.*—Does this ever occur and if so how is the electrical conductivity of the salt affected?

20—*Electrical Conductivity.*—The investigation of electrical conductivity should include:

(*a*)—The E. C. of all the elements which maintain the solid or liquid phase at high temperature. The so called insulators which are elementary substances, as liquid sulphur, should be carefully examined for their electrical conductivity when at high temperature and under such pressure as can be obtained.

(*b*)—E. C. of the metallic elements in the vapor phase at different pressures and different temperatures. Experiments already made by the writer (*Journal* of the Franklin Institute, March, 1915) show that the conductivity depends upon many factors and when measured between a tungsten wire and the walls of a graphite cylinder in which the wire is axially located, is asymmetric; that is the conductivity depends upon the polarity of the wire. Furthermore, different results are obtained when the conductivity is measured with alternating current of different frequencies.

(*c*)—The E. C. of the non-metallic elements in the gaseous phase at high temperature and under high pressure. (The conductivity at low pressures has been extensively investigated.)

(*d*)—The E. C. of several metallic alloys when molten has been examined, but many yet remain.

(*e*)—The E. C. of molten salts for alternating current of different frequencies.

(*f*)—The E. C. for direct current of molten salts under conditions which would reveal an asymmetric conductance, if it exists.

(*g*)—The E. C. at high temperature of standard refractory materials and a determination of the percentage of the conductivity which may be ascribed to hot gases contained in the interstices of the refractories.

(*h*)—A study should be made of the cause of an apparent increase, observed by the writer, in the specific inductive capacity of both hot gases and refractories when attempting to measure the E. C. of these with alternating current of different frequencies.

21—*Electromotive Force.*—The study of the production of e.m.f. chemically in primary cells has been confined for the most part to aqueous solutions at ordinary temperature. There is a large field for investigation at high temperature of the e.m.f. obtainable; (a) between two fused salts separated by a porous partition (b) between a fused salt and a solid, and (c) between two fused metals separated by a porous partition of compressed tungsten powder. May not primary batteries of very considerable e.m.f. and of possible high efficiency result from this study? Should not the matter be reopened of attempting the consumption of carbon in a manner to give rise directly and efficiently to electrical energy? This is one of the great problems which investigations with high temperature are most likely to solve.

The writer has observed that when working above 1200° C. that practically all combinations of two or more materials give rise to electromotive forces—often very troublesome when accurate measurements are being attempted. In fact, because of this, all his measurements of electrical conductance at high temperature of the metals are now made with an alternating-current galvanometer as a detector and alternating current of 25 cycles as the measuring current. The magnitude and the causes of these electromotive forces in the case of certain combinations of typical materials deserve investigation.

22—*Thermoelectromotive Force.*—We have to inquire, (a) What are the thermoelectromotive force curves at high temperature of combinations of solids, (b) of combinations of metallic liquids (as molten tin versus molten lead) (c) of combinations of metallic vapors (as zinc vapor versus cadmium vapor), (d) of the combinations of the solid versus liquid phase of the same metal, (e) of combinations of a solid metal versus another liquid metal, (as W versus molten Sn), (f) of combinations of molten salts.

How little we know about these matters may be determined by consulting any of the standard tables of the physical constants.

23—*Specific Inductive Capacity.*—There are reasons to suppose that a slab of refractory material contained between two slabs of graphite will exhibit the phenomena above 1200° C. of a very leaky condenser having a dielectric of large specific inductive capacity.

24—*Thomson and Peltier Effects.*—As far as the writer knows these phenomena have only been studied at ordinary temperatures.

25—*Mechanical Forces.*—It is always assumed, but as far as the writer knows has never been experimentally proved, that inertia and centrifugal force exist unchanged in matter at all temperatures and obey the same Newtonian laws at 4000° K. as they do at ordinary temperature. Should not this assumption be tested? For example, suppose a large spherical pendulum bob were filled with thermit, would the period remain unaltered while the thermit reacted? The writer is mentally constituted so that he takes nothing for granted regarding which there is an opportunity for obtaining experimental evidence.

26—*Engineering Data.*—There is an unlimited quantity to be obtained of engineering data regarding the physical properties of matter at temperatures exceeding 1200° C. The limitations of the nichrome and platinum-wound laboratory furnaces are largely responsible for the paucity of information respecting the physical properties of matter above 1100° C. or 1200° C.

The above article has been written for the double purpose of assisting the writer in the selection of the problems of high-temperature investigation which he would attack, and to present to the readers of this journal (in an all too inadequate way) the immensity and the fruitfulness of this rapidly enlarging field of investigation. The greatest results can only be expected through interested co-operative effort.

The chemical field and the construction of practical devices have not been considered, though it is probable that the most important developments commercially will come from a study of high-temperature chemistry. It is in the study of high-temperature chemistry, which the writer thinks should be called electrothermics, rather than in the study of high-temperature physical problems that the greater progress commercially may be expected.

Palmer Physical Laboratory,
Princeton, N. J.

The International Engineering Congress announces that the technical success of the Congress is now well assured. From 200 to 250 papers will be presented, representing 18 different countries, so that the Congress will be truly international in character. Membership in the Congress with the privilege of purchasing any or all volumes is open to all interested in engineering work.

Monazite sand in Brazil is found in commercial quantities only on the foreshore at certain points on the coast of the state of Espirito Santo and a few miles north of the town of Prado, in the state of Bahia. The foreshore belongs to the government and leases are granted under the direction of the Minister of Finance. There are at present two active concessions and one passive.

Exports of tin from the Federated Malay States from July 1 to December 31, 1914, amounted to 24,140 tons, as compared with 26,244 tons in the corresponding period of 1913. The total exports of tin for 1914 amounted to 49,042 tons, as compared with 50,128 tons in 1913.

Stratton's Independence milled during December, 1914, 9400 tons of low-grade mine and dump ore. The net profit to the company for the month was $6700.

Leaching a Zinc-Lime Ore with Acids[k]

BY O. C. RALSTON AND A. E. GARTSIDE

In looking over the low-grade and complex ore resources of Utah, it was found that in the two largest mining districts in the State there was a certain type of ore which consisted essentially of calcium and zinc carbonates, more or less associated with some insoluble silica and silicates, the zinc ore being a replacement in limestone.

The following analysis of ore, from the May Day mine, of the Tintic district is representative: Insoluble, 37.4 per cent; CaO, 12.96 per cent; Fe, 4.19 per cent; Al_2O_3, trace (acid soluble); Zn, 15.7 per cent; Pb, 0.55 per cent; Au, 0.24 oz. per ton; Ag, 0.30 per cent; S, 0.65 per cent; CO_2, 19.84 per cent.

An approximate mineralogical analysis calculated from these data, dividing CO_2 between CaO, Zn, and Pb, would be:

	Per Cent
Silica, SiO_2	37.40
Limestone, CaO_3	23.15
Limonite $(Fe_2O_3)_2(H_2O)_3$	6.00
Pyrite, FeS_2	1.20
Calamine, $H_2Zn_2SiO_5$	2.31
Smithsonite, $ZnCO_3$	27.70
Cerussite, $PbCO_3$	0.70
Total per cent	97.46

The undetermined material perhaps includes some alumina, as well as some water of composition, provided part of the smithsonite has been altered to hydrosincite. The above analysis, however, accords fairly well with a qualitative microscopic examination of the ground sample.

There are several other types of oxidized ores of zinc which are much more abundant, but this one is of interest on account of the high percentage of lime and the rather large amount of gold present, the presence of this such gold being somewhat unusual in the Tintic district[1], at least for a zinc ore in limestone.

It is of considerable interest to see whether the zinc could be leached out of the ore with acids or other solvents as a preliminary to cyaniding the gold. To maintain a fairly pure electrolyte for the decomposition of zinc, it is necessary to keep the iron from going into solution. As this particular ore contains such a low percentage of iron it probably would not be difficult to keep the electrolyte reasonably free from iron, while the presence of lime would doubtless be permissible in such a electrolyte because it does not deposit at the decomposition voltages of the zinc salts. However, it can cause trouble in another way, for when currents of high density are used, a sparingly soluble hydrate is formed at the cathode. On account of the low solubility of calcium sulphate, this latter trouble is rarely met in a solution resulting from sulphuric acid leaching.

However, the precipitation problem was left till it was possible to see what could be done with acid leaching; therefore, the purpose of this paper is to report only what seem the most fundamental and important results of these acid leaches, without too much detail regarding connected problems. Other types of leaching, such as alkaline ammonium carbonate, caustic soda, etc., have been tried, but will be reported later.

Leaching with hydrochloric and sulphuric acids was given first consideration for the reason that both can be made very cheaply in the Salt Lake Valley, the one from the salt in the Great Salt Lake, which is present in amounts varying around 26 per cent by weight, and the other from the SO_2 of the smelter gases from four large smelting plants, all within thirty miles of one another and not more than a hundred miles distant from most of the deposits of ore.

Three series of tests were run on the raw ore, crushed to 150 mesh to liberate the zinc minerals as thoroughly as possible, and in lots of 33.33 gms. for each test, with varying amounts of acid and water to make up 100 cc of solution.

The proportions used in these tests were such as to suit the leaching bottles at hand, which were of the ordinary 150-cc type often used for agitation tests in cyaniding. The bottles were placed in an agitator which turned them over completely, end for end, about once every second. All of the acid tests were carried on at room temperature. The pulp after agitation was filtered either with a Buechner funnel or with the alundum filtering dishes now to be had on the market, portions of the filtrate taken for titration and the tailings washed, dried and weighed. The filtrate was analyzed for zinc, lime and iron to check up the analyses for the same elements, on the heads and tailings. The final acidity was also determined in the filtrate.

Description of the Tests.—In the first series of tests identical samples were treated with each acid in amounts insufficient to dissolve the zinc and lime in the lower concentrations, up to amounts of acid sufficient to dissolve all the zinc, lime and iron and still allow residual acid. These are the No. 1 leaches recorded in Table I.

The second series of tests was much the same as the first with the exception that chloride of lime was added to the solutions in anticipation of the solution of the gold by means of the chlorine liberated by the action of acid on the chloride of lime. These leaches are the No. II leaches recorded in Table I. Whether such a method would be advisable in practice is open to question, but it must be remembered that application of cyaniding after acid leaching will require neutralization and probable high consumption of cyanide. Direct application of the old chlorination process, however, could make this a "one-solution" process.

The last series of tests, numbered III in Table I, was run with amounts of acid sufficient to dissolve only about one-fourth of the zinc and lime in each leach, and four of these leaches in succession were applied to the ore. That is, the samples in duplicate, were given a leach with a solution of acid which had seemed by previous tests to be the most advantageous in the dissolving of zinc selectively as compared with the lime, and in amount sufficient to dissolve only a little more than a fourth of the zinc and lime present in the ore. After agitation and filtration the so lution was taken for analysis and the residue leached with the same amount of the same acid, again filtered, dried, weighed and treated in the same way twice again. By this time most of the zinc had been leached out and the tests were discontinued. The object of the series was to compare the two acids in efficiency at different parts of the leach and to see in what order the constituents of the ore went into solution.

The Results. All of the data of the tests are to be found in Table I, just described.

Taking tests I-a to I-f, where hydrochloric acid is solvent, it can be seen that there is sufficient acid in I-a and I-b to dissolve only the zinc in the ore. The result that is of interest from these first two tests is the acid efficiency (amount of acid consumed per unit of zinc extracted) rather than the extraction of the zinc obtained.

The amount of acid necessary to dissolve all the zinc in the samples treated is 5.83 grams. The efficiency of

[k]Contribution from the Metallurgical Research Laboratory, D. Lyon, metallurgist in charge, of the University of Utah, in cooperation with the U. S. Bureau of Mines. O. C. Ralston is assistant metallurgist of the U. S. Bureau of Mines.

[1]G. F. Loughlin, "The Oxidized Zinc Ores of the Tintic District, Utah." *Econ. Geol.* (1914), page 1.

Table I

Test No.	Wt. Heads, Grams	Wt. Tails, Grams	Time in Hours	Acid	Acid Strength Lb./Ton	Acid Strength %	Acid Grams Acid Before	Acid Grams Acid After	Acid Grams Acid Consumed	Efficiency lb. Acid / lb. Zinc	Efficiency %	CaO Grams Heads	CaO Grams Tails	CaO % Ext.	Fe Grams Heads	Fe Grams Tails	Fe % Ext.	Av. Ounces Heads	Av. Tons Tails	Av. % Ext.	Zinc Grams Heads	Zinc Grams Tails	Zinc % Ext.	$CaCO_2$ Used Grams	$CaCO_2$ Used Lbs. per Ton Ore
I. a	33.33	31.7	21	HCl	40.5	2	2.025	0	2.025	2.38	46.7	4.32	3.83	11.34	1.45	1.45	0				5.23	4.28	18.15		
b	33.33	29.5	21	HCl	81.0	4	4.05	0	4.05	2.16	51.5	4.32	3.45	20.16	1.45	1.45	0				5.23	3.26	37.8		
c	33.33	20.5	21	HCl	203.0	10	10.15	0	10.15	2.43	45.8	4.32	1.47	66.0	1.45	1.45	0				5.23	1.05	80.		
d	33.33	32.9	22	HCl	224	11.2	11.2	0	11.2	2.30	48.4	4.41	0.98	77.7	1.60	1.60	0				5.43	.57	89.5		
e	33.33	33.0	22	HCl	224.	11.2	11.2	0	11.2	2.30	48.4	4.41	0.95	78.5	1.60	1.60	0				5.43	.57	89.5		
f	33.33	22.1	22	HCl	340	17.0	17.0	2.75	14.25	2.62	42.5	4.41			1.60	1.60	0				5.43	....	....		
g	33.33	32.9	21	H_2SO_4	38.5	2.	1.975	0	1.975	4.20	35.8	4.32	4.32	0	1.45	1.45	0				5.23	4.76	8.98		
h	33.33	31.9	21	H_2SO_4	76.75	4.	3.838	0	3.838	2.52	59.6	4.32	4.32	0	1.45	1.45	0				5.23	3.71	29.04		
i	33.33	30.7	21	H_2SO_4	185.0	10.	9.25	0	9.25	2.70	55.6	4.32	4.32	0	1.45	1.45	0				5.23	1.80	65.06		
j	33.33	28.2	22	H_2SO_4	303.5	15.2	15.175	0	15.175	3.19	47.0	4.41	4.41	0	1.60	1.60	0				5.43	.68	87.5		
k	33.33	28.0	22	H_2SO_4	303.5	15.2	15.175	0	15.175	3.19	47.0	4.41	4.41	0	1.60	1.60	0				5.43	.68	87.5		
l	33.33	26.2	22	H_2SO_4	454	22.7	22.7	3.8	18.9	3.75	40.0	4.41	4.41	0	1.60	1.24	22.45				5.43	.39	92.9		
II. a	33.33	31.3	16.5	HCl	40.5	2	2.025	0	2.025	4.3	25.9	4.99	3.93	21.2	1.42	1.39	0	0.24	0.08	66.6	5.03	4.56	9.3	1.67	100
b	33.33	31.75	16.5	HCl	40.5	2	2.025	0	2.025	11.24	9.9	5.68	4.22	25.7	1.42	1.38	Trace	0.24	.08	66.6	5.03	4.85	3.6	3.33	200
c	33.33	28.8	16.5	HCl	81.0	4	4.05	0	4.05	3.09	36.0	4.99	3.37	32.5	1.42	1.40	Trace	0.24	.12	50.0	5.03	3.72	26.0	1.67	100
d	33.33	29.16	16.5	HCl	81.0	4	4.05	0	4.05	2.96	37.6	5.68	3.55	37.5	1.42	1.39	Trace	0 24	0.6	75.0	5.03	3.76	25.1	3.33	200
e	33.33	33.84	16.5	H_2SO_4	38.5	2	1.975	0	1.975	5.05	29.7	4.99	4.81	3.6	1.42	1.38	Trace	0.24	.16	33.3	5.03	4.64	7.8	1.67	100
f	33.33	35.04	16.5	H_2SO_4	38.5	2	1.975	0	1.975	13.17	11.4	5.68	5.13	9.7	1.42	1.41	0	0.24	.16	33.3	5.03	4.88	3.0	3.33	200
g	33.33	32.89	16.5	H_2SO_4	76.75	4	3.838	0	3.838	2.89	52.0	4.99	4.87	2.4	1.42	1.40	Trace	0.24	.16	33.3	5.03	3.70	26.4	1.67	100
h	33.33	35.3	16.5	H_2SO_4	76.75	4	3.838	0	3.838	5.40	27.8	5.68	5.52	2.8	1.42	1.50	Trace	0.24	.14	41.6	5.03	4.32	14.1	3.33	200
III. a	33.33	28.38	17	HCl	81.0	4.05	4.05	0	4.05	1.85	60.0										5.23	3.05	41.7		
	33.33	23.24	17	HCl	81.0	4.05	4.05	0	4.05	2.45	45.5										5.23	1.40	73.3		
	33.33	17.7	18	HCl	81.0	4.05	4.05	0	4.05	5.12	21.7										5.23	.61	88.3		
	33.33	13.1	18	HCl	81.0	4.05	4.05	2.1	1.95	3.70	30.1											.11	37.7		
b	33.33	28.43	17	HCl	81.0	4.05	4.05	0	4.05	1.90	58.8										5.23	3.10	40.8		
	33.33	23.19	17	HCl	81.0	4.05	4.05	0	4.05	2.50	44.7											1.48	71.7		
	33.33	17.37	18	HCl	81.0	4.05	4.05	0	4.05	4.50	24.7											.58	88.9		
	33.33	12.97	18	HCl	81.0	4.05	4.05	2.2	1.85	3.78	29.4											.11	98.0		
c	33.33	31.38	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.60	58.4										5.23	3.75	28.3		
	33.33	28.47	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.65	56.8											2.30	56.0		
	33.33	25.05	18	H_2SO_4	76.8	3.84	3.84	0	3.84	3.69	40.6											1.26	75.9		
	33.33	23.15	18	H_2SO_4	76.8	3.84	3.84	0	3.84	11.63	13.0											.93	82.3		
d	33.33	31.75	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.54	59.2										5.23	3.72	28.5		
	33.33	28.36	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.48	60.5											2.17	58.5		
	33.33	25.12	18	H_2SO_4	76.8	3.84	3.84	0	3.84	3.84	39.1											1 17	77.6		
	33.33	23.0	18	H_2SO_4	76.8	3.84	3.84	0	3.84	13 92	11.5											.88	83.1		

the acid in these two tests, expressed in "per cent of the acid used up which was used to dissolve zinc," was 46.7 per cent and 51.5 per cent respectively. This shows that in spite of using such a small amount of acid, it was not possible to make all of it go toward dissolving zinc alone, but that instead some of it went to dissolve other soluble constituents of the ore. By testing the leach solution it was found that the rest of the acid dissolve the lime, and almost no iron was dissolved.

Test I-b is known to have suffered a small leak during agitation, causing a loss of acid, but being identical with test III-a, was not repeated. The efficiency of acid in test III-a was 60 per cent.

Test I-c was with more than enough acid to dissolve all the zinc but not quite enough to dissolve in addition all the lime. An 80 per cent extraction of the zinc was obtained, but the figure on efficiency of the acid fell to 45.8 per cent, a result which seems to be low when compared with the next two tests which were run in duplicate.

These two tests, I-d and I-e, were run with just sufficient acid to dissolve all the zinc and lime in the ore, but no iron. An 89.5 per cent extraction of the zinc resulted, with an efficiency of acid expenditure of 48.4 per cent, but it was noticed that a trace of iron was beginning to dissolve.

Finally, test I-f was run with sufficient acid to dissolve all the zinc, lime, and iron. The results show that after twenty-hours of contact a good portion of the iron had not dissolved, as considerable free acid was left in solution.

Summing up this series of tests with hydrochloric acid, we see that it is possible to get an 80 per ecnt extraction of zinc, or better, with about a 50 per cent efficiency of acid to give a solution that is practically free of iron and hence admirably adapted to electrolysis of the solution for obtaining the zinc. This is because lime does not tend to deposit at the voltage necessary for deposition of zinc, and, moreover, because there is no excess acid in this solution.

By increasing the amount of acid applied while the increased extraction of zinc is small, iron tends to go into solution and excess of acid is left, both results being undesirable from the standpoint of electrolytic precipitation. Direct production of metal and regeneration of acid are, of course, the main reasons for wanting to use electrolytic precipitation. The acid efficiencies of this series of tests are shown plotted in Curve I.

In passing it might be well to call atention to the utility of the units used in Curve I. Here, plotted against the various strengths of acid, are to be found the efficiencies of the acid expressed in two different units. For use by the mill man we have expressed the acid efficiency in terms of "lbs. acid used up per lb. zinc, dissolved." For more general application, however, we have also expressed the acid efficiency by giving percentage of the consumed acid which was used in dissolving zinc. This immediately shows what percentage of the acid is used in dissolving materials other than zinc, while the mill man's "lbs. acid per lb. zinc" does not show what efficiency is obtained until his figure is compared with the amount of acid necessary to dissolve 1 lb. zinc where no acid is wasted. This amounts to 1.112 lb. HCl per lb. zinc in the case at hand and 15 lb. of H_2SO_4 per lb. of zinc when sulphuric acid is used. The strengths of acid used are also expressed in two sets of units—one in percentage by weight of acid in the solution and the other in pounds acid per ton of solution used. This method of having both practical and absolute units should prove useful and save transposition of figures.

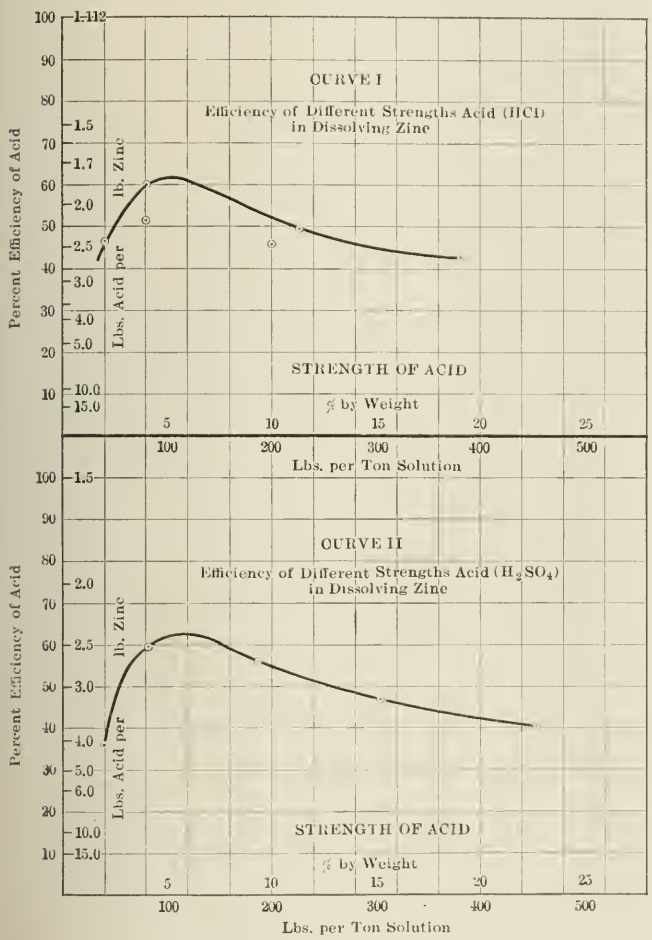
Tests, I-g to I-l (Curve II) with sulphuric acid, were conducted in exactly the same sequence, the first three being with increasing amounts of acid, insufficient in every case to dissolve all the zinc and lime, while the next two are duplicates with an amount of acid just sufficient to dissolve zinc and lime and the last one with an amount of acid sufficient to dissolve all the zinc, lime, and iron. The iron did not dissolve appreciably until the last test, but here again we find that only a portion of the iron was soluble so that some free acid was left.

The percentages of extraction of the zinc tend to run a few per cent lower than in the case of hydrochloric acid, when compared on a pound for pound basis, but it

must be remembered that the chemical equivalent of a pound of sulphuric acid is less than that of a pound of hydrochloric acid, being roughly $\frac{72}{98}$.

The plot of acid efficiences for H_2SO_4 (Curve II) shows a very smooth curve with a decided maximum at a point where about 6 per cent strength of acid is used, and this maximum attainable efficiency is 63 per cent. A like maximum would seem to be discernible in the case of the tests with hydrochloric acid (Curve I) but not enough points have been determined to place it exactly.

Again, we find it possible to get up to an extraction of 87.5 per cent with an acid efficiency of 47 per cent, while to go further in extraction of the zinc lowers the acid efficiency, fails to increase appreciably the amount of zinc extracted, and takes iron into solution, as well as leaving unconsumed acid to hinder electrolysis.


CURVE I
Efficiency of Different Strengths Acid (HCl) in Dissolving Zinc
Percent Efficiency of Acid
Lbs. Acid per lb. Zinc
STRENGTH OF ACID
% by Weight
Lbs. per Ton Solution
CURVE II
Efficiency of Different Strengths Acid (H_2SO_4) in Dissolving Zinc
Percent Efficiency of Acid
Lbs. Acid per lb. Zinc
STRENGTH OF ACID
% by Weight
Lbs. per Ton Solution

FIGS. 1 AND 2—EFFICIENCY CURVES

It is an interesting coincidence that if we examine the analysis of the ore we find, with respect to the two soluble constituents, zinc and calcium, the perecentage of zinc is 63 per cent of the sum of the zinc and calcium, while our maximum acid efficiency is likewise at 63 per cent. In other words, at the point of maximum efficiency zinc and lime go into solution in amounts proportionate to the percentages in which they are present in the ore, with no preference in solubility for either constituent. As calcium stands higher than zinc in the electromotive series, this point of non-selective solubility is of considerable interest and its explanation is not exactly clear.

The tests numbered II were made with insufficient acid to dissolve all the zinc; furthermore, varying amounts of chloride of lime were added to supply chlorine for solution of the gold. The zinc extractions were very low, because much of the acid combined with the chloride of lime (which contained 41.6 per cent CaO). On that account the zinc extractions and the efficiencies of expenditure of the acids are of little interest for the time being and only the extractions of gold will be noted. It is seen that in all cases the extractions of the latter were higher in leaches containing hydrochloric acid and bleaching powder than in those leaches where sulphuric acid was used with bleaching powder; however, the amount of bleaching powder used to get these extractions was rather large, varying from 3 to 10 per cent of the weight of the ore. This highest extraction of gold was 75 per cent.

However, tests of this magnitude and under these conditions are not regarded as conclusive, so the inference is that the gold seems to be somewhat readily soluble in solutions containing chlorine. The extraction of the gold will not be further considered in this connection, for the special object of this paper is to call attention to the possible acid efficiency in extracting zinc from an ore so high in lime.

Going back to the maxima in the acid efficiency

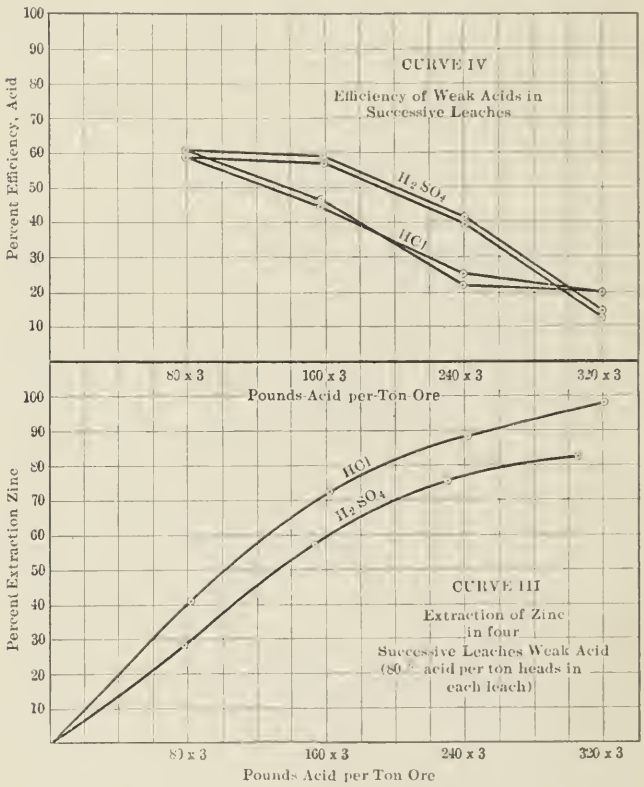


FIG. 3 AND 4—EFFICIENCY AND EXTRACTION CURVES

curves, we find that a certain strength of solution seemed to give the most advantageous conditions for leaching and since not enough acid had been used to extract all the zinc, it was thought advisable to see if successive leaches of acid of this strength would extract all the zinc, and whether they would change in their acid efficiency.

These tests constitute III-a to III-d—III-a and III-b being duplicates with four successive leaches of HCl, and III-c and III-d being duplicates of H_2SO_4 leaches—four in succession in each case.

The results are plotted in curves III to V. Curve III shows the percentages of zinc extracted after each successive leach, there being four points determined on the curve for each acid. Again we find that, pound for pound, hydrochloric acid will extract more zinc than sulphuric acid.

In order to see if a chemical equivalent of H_2SO_4 would dissolve as much as a chemical equivalent of HCl, the units of Curve III were changed from "pounds per ton" to "moles of acid used," and replotted in curves V. We find from this diagram that hydrochloric and sulphuric acid give identical curves and extract exactly the same percentage of zinc, as far as the chemical equivalents go. Though chemically, one is no better than the other, at the same cost per pound, the hydrochloric acid would have the advantage.

Curve III is of interest to the mill man, while Curve V is of interest to the scientist. The fact that the two acids do exactly the same chemical work is very interesting when we remember the different solubilities

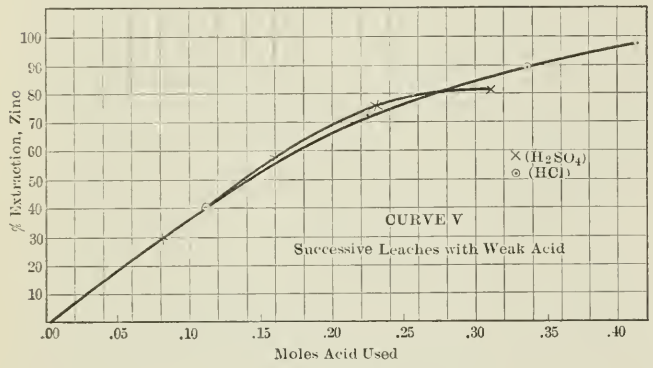


FIG. 5—EFFICIENCY CURVES

of $CaCl_2$ and $CaSO_4$ as well as the other factors which could cause differences in the amount of zinc dissolved in the presence of lime.

The individual efficiencies of each of these same leaches are shown in Curve IV, and rather than take averages of the duplicates, the four tests are plotted separately to show how nearly the duplicates check each other, and to give an idea of the reproducibility of the work. These curves could likewise be replotted with moles of acid as a unit instead of pounds of acid but we know from Curve V that they would fall very close to one another, and hence it is unnecessary.

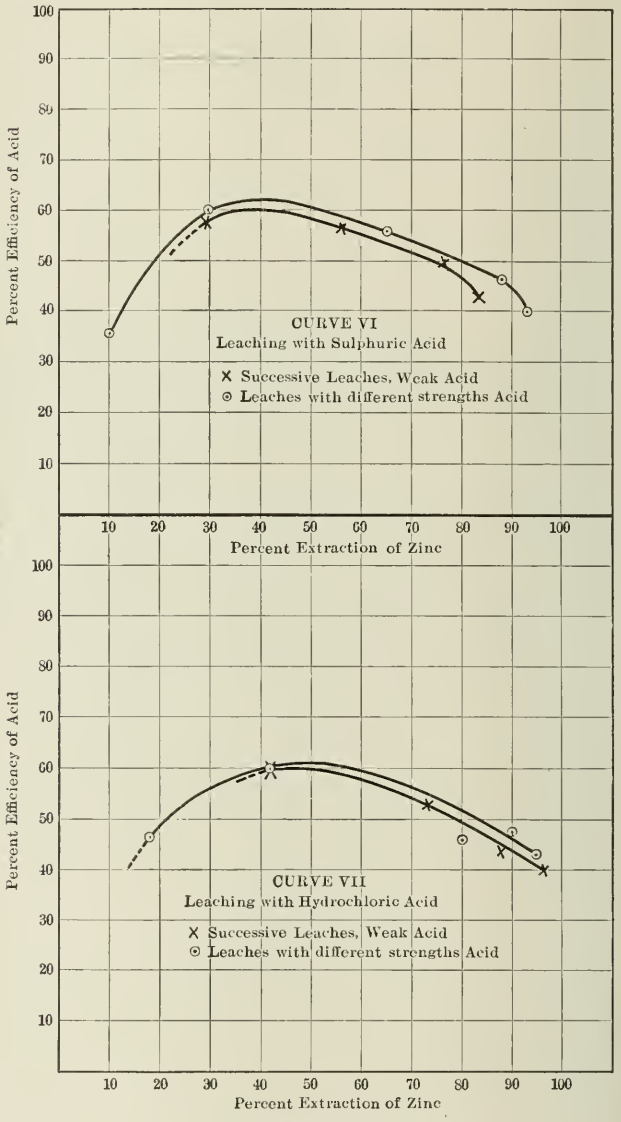
It is interesting in looking over this last series of tests to see that we check our former work of 60 per cent efficiency of acid when about 80 lbs. acid per ton of solution are added but that, as more and more zinc is extracted, the acid efficiency falls off. Suspecting that this drop in efficiency might be due to the same causes that made the higher strengths of acid less efficient, it was thought best to try to compare the tests of Series I with those of Series III by plotting the percentage extraction of the zinc for each experiment against the percentage efficiency of expenditure of the acid.

This is done in Curves VI and VII. The point marked by crosses and the curves drawn through them represent the results of the series of successive leaches with weak acid of the same strength in each leach, while the points marked by circles show the results of the separate tests with different strengths of acid.

The two sets of results seem to give curves that are practically identical. To express this fact we now have to say that as long as you take a certain amount of ore and treat it with a certain amount of acid, you get the same extraction of zinc and use up a certain percentage of the acid usefully, no matter if the acid be applied in one leach or if it is divided into a number of separate leaches.

Furthermore, as one curve is for a constant strength of acid and the other for different dilutions, and the curves are identical, we can say that no matter what the dilution a certain number of pounds of acid can extract only a certain percentage of the zinc and at only a certain percentage efficiency of expenditure of the acid. This result is of fundamental importance for it shows that no further experimenting with various strengths of acid need be tried on this particular ore and whatever the sizes of material employed a similar relation should be found.

Knowing then that we may use acid of any dilution that we please, as long as we get a sufficient quantity in contact with the ore to dissolve the desired quantity of zinc, the considerations which will determine the strength of acid to be used in mill solutions, will depend entirely on the mechanical point of view and different designers will have various opinions as to the best way to take advantage of this fact. So Curve VIII, giving the number of pounds of acid to extract any definite number of pounds of zinc (or to extract any definite percentage of zinc), no matter at what dilution



FIGS. 6 AND 7—EFFICIENCY CURVES

it is applied, will be of the highest practical utility.

Further considerations as to the largest allowable size of crushing of the ore, necessary time of contact, screen analysis, and possibllity of treating slimes and sands separately, as well as the possible influence of temperature on the inner relations and velocity of such leaches have not been investigated thoroughly yet, but the rather unusual turn of events met with in the

course of this series of tests seemed enough to warrant their publication.

Summary: A series of leaches with hydrochloric and sulphuric acids on a zinc lime ore has revealed that if insufficient acid to be added to dissolve the zinc, the efficiency of expenditure of the acid increases to a maximum of 63 per cent (the percentage which zinc forms to the total soluble material) but that further addition of acid to extract further zinc causes the efficiency of expenditure of the acid to fall off more and more to nearly 40 per cent when all the zinc is extracted. These figures are true for both acids.

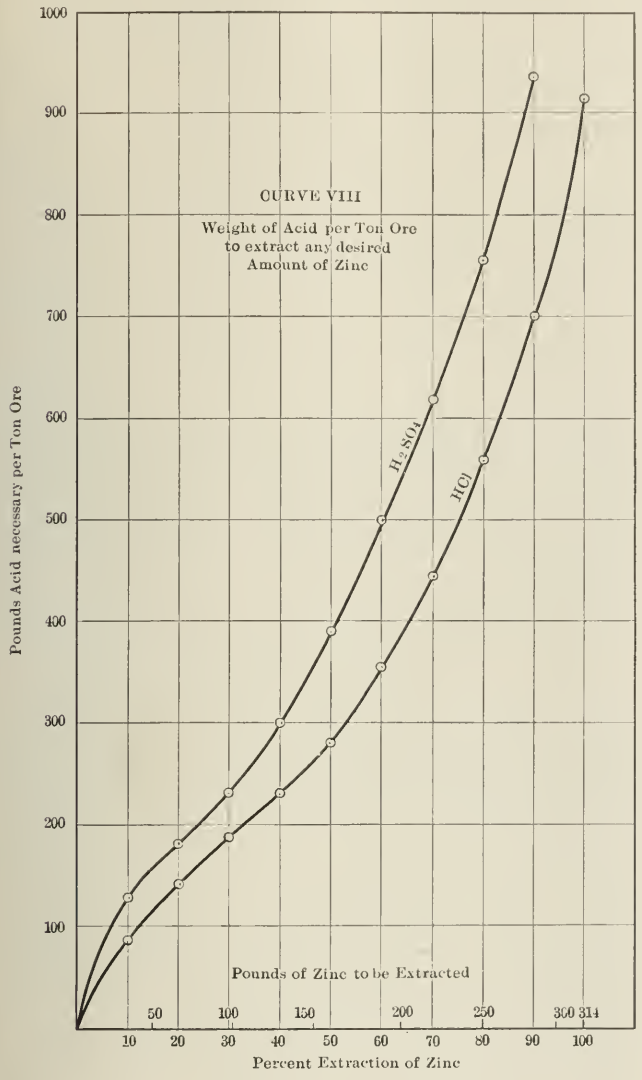


FIG. 8—EXTRACTION CURVES

Chemically, molecule for molecule, the two acids do exactly the same work, a result somewhat surprising in view of the solubility and other relations of the various salts formed. However, the higher chemical equivalent of a pound of hydrochloric acid would give it the commercial advantage of the same cost per pound.

The curious fact has been discovered that no matter at what concentration it is applied, a given amount of acid does the same work; hence the curve of the percentage extraction of zinc plotted against percentage acid efficiency, is the same for all strengths of acid.

It seems possible, by adding chlorine to the leaching solution to get a simultaneous extraction of both zinc and gold, though there is some question as to its desirability.

University of Utah,
Salt Lake City, Utah.

The Determination of Manganese in Ferrovanadium

BY WILLIAM W. CLARK

The determination of manganese in ferrovanadium is not a serious problem as it can be determined by any one of several different methods, modified to suit the interfering elements present, and as the presence of manganese is not detrimental to steel, in which the majority of the alloy is used, the very accurate determination of it is not a commercial necessity.

Manganese which is added to ferrovanadium in percentages ranging from 0.25 per cent to 10 or 12 per cent has several beneficial properties. It enables the manufacturer to turn out an alloy, which is low in sulphur content, from an ore or oxide which contains considerable of that harmful element. To the user it offers several possibilities. It saves the heat in his steel when the ferrovanadium is added to the ladle, as manganese serves the double purpose of lowering the melting point of the alloy and of increasing its solubility in the molten steel. It saves the addition of a corresponding amount of manganese as ferromanganese, and it also increases the amount of vanadium recovered in the steel. As manganese has a greater heat of combination with oxygen than vanadium and will reduce vanadium oxide to the metal at the temperature of molten steel, it acts as a scavenger, which is more active than vanadium, and thus combines with some of the oxygen contained in the steel as oxides, which would otherwise be combined with and carried out by the vanadium.

The method for the determination of manganese in which the presence of vanadium interferes is the Ford-Williams method. In view of the fact that when a vanadium solution is boiled with strong nitric acid, vanadic acid separates, and also when chlorates are added, the liberation of chloric and chlorous acid precipitates vanadic acid from acid solutions almost completely, and as such a precipitate would be titrated as manganese, the method is useless.

The Volhard method can be used by observing certain precautions, mainly that of keeping the vanadium oxidized to its highest valency. This can be accomplished by using an excess of nitric acid, which will not interfere with the titration in any way, except in the presence of hydrochloric acid, which must be absent. The method in detail is:

The finely powdered alloy is dissolved in nitric-sulphuric acids, evaporated to small bulk, a few cc of concentrated nitric acid added, the solution boiled to remove all nitrous fumes, diluted, and almost neutralized with sodium carbonate solution. An excess of zinc oxide emulsion is then added and the solution is boiled for one minute. An aliquot portion can then be filtered off, over a dry paper and titrated, but it has been found that the presence of the precipitate in the solution is rather beneficial than harmful. The precipitate of vanadium and iron, which settles rapidly, envelops and carries down the slow-settling manganic oxide, thus saving time and making the end point sharper. There is a small correction factor to be determined, as it has been found that the theoretical factor will not give the actual content. This factor is determined by making a synthetic standard ferrovanadium from alloy free from manganese and a weighed portion of the Bureau of Standards manganese ore. Following are results obtained by this method:

The method using lead peroxide as an oxidizing agent could also be used but it requires a filtration which is objectionable, and it also demands the absence of sulphuric and hydrochloric acids, which are hard to remove, and the alloy breaks up with difficulty in nitric acid.

Manganese present Per cent	Manganese recovered Per cent
1.00	1.02
	1.03
	1.01
	1.00
	1.01
5.00	5.07
	5.02
	4.98
10.00	9.88
	9.92
	9.94

The method worked out by Dr. Cain using basic carbonates and oxides to precipitate the vanadium, free from manganese, and the manganese determined in the filtrate, can also be used and very good results are obtained, but it also has to be filtered. A slight modification of this method gives good results, and consists in reducing the vanadium by evaporation with hydrochloric acid, thus having the iron oxidized and the vanadium reduced, and then precipitating the iron and vanadium together, and determining the manganese in the filtrate.

The method which has been found to be the most accurate on all percentages of manganese found in commercial alloys is the persulphate method with the subsequent titration of the permanganic acid by sodium arsenite solution, which does not reduce the vanadium as does ferrous sulphate. The titration of the permanganic acid is always to be preferred instead of the comparison of the color with a standard of approximately the same percentage. The standard is not always available, and the yellow of the vanadium is not standard as different acidities give different tones, and what is of more importance, the titration is more accurate and can be done more quickly.

The method in detail is as follows:

0.2 gram of finely powdered alloy is dissolved in 10 cc of a nitric-sulphuric acid mixture (200 cc H_2SO_4, 200 cc HNO_3, and 400 cc H_2O) with the addition of a little hydrofluoric acid, if the alloy is refractory to these acids. The solution is vigorously boiled, diluted to 100 cc, 10 cc of a silver nitrate solution added (1.25 grams per liter) and an excess of solid ammonium persulphate. The solution is brought to a boil and cooled at once in cold water, a few drops of saturated solution of salt is added, and the manganese titrated to the disappearance of the last trace of pink. The operator can catch this point very exactly after a few trials, as the end point is very sharp and can be caught with one drop of the solution. In case the manganese content is above 5 per cent, the solution is diluted and an aliquot portion taken before adding the silver and persulphate. The general idea for this method is that it is not applicable for percentages above 1.5 or 2 per cent, but after using it for a number of years it has been found to be as accurate as any of the other methods on materials containing as high as 15 per cent manganese. The only precautions to be observed are that there must not be more than 0.01 gram manganese for each 100 cc of solution; chlorides must be absent and the acidity must not be too high. Larger amounts of manganese than above mentioned will cause a precipitate of manganic oxide in the solution, which does not titrate theoretically. Even with the above amount in case the acidity is too low, there is sometimes a precipitate, but it can generally be cleared up with a few drops of nitric acid.

The arsenite solution is made by dissolving sodium arsenite in water and standardizing against a standard ferrovanadium made from manganese free alloy and the Bureau of Standards manganese ore. The solution most used is standardized so that 1 cc will equal 0.05 per cent manganese on a 0.2-gram sample. The addition of the salt solution is also very necessary as it combines with the silver, rendering it quiescent. Otherwise the silver still being active as a catalytic agent, slowly reoxidizes the manganese during the titration, and while this is of no importance on a low value, on a high one, in view of the fact that the error so introduced is multiplied in accordance with the aliquot portion, it is considerable. The method is very rapid, taking only about fifteen minutes when the aliquot portion is not required, and then only a few minutes longer. Following are results obtained from this method, showing that it is possible to obtain concordant results commercially:

Manganese present Per cent	Manganese recovered Per cent
0.50	0.49
	0.48
	0.50
	0.51
	0.50
1.25	1.23
	1.24
	1.27
	1.22
	1.24
5.00	4.92
	4.94
	4.96
	4.94
10.00	9.90
	9.88
	9.92
	9.92
	9.90
15.00	14.96
	15.04
	15.06
	14.95

The determinations for the 0.50, 1.25, 5.00 and 10.00 were titrated with a solution standardized against the 0.50 per cent, while the 15 per cent was standardized against a 15.00 alloy. By using weighed burettes closer results might be obtained, but the above are close enough for any commercial purposes.

Seymour Mfg. Co.,
Seymour, Conn.

The Purification of Boiler Feed Water

BY EVERARD BROWN

It is a well-known fact that the use of bad water for boiler feed purposes is not conducive to satisfactory and economical steam plant operation. It is also true that natural waters are hardly ever pure, no matter what their sources may be, and instances are indeed rare where the water is fit to be used for making steam without its receiving treatment of some kind either before or after its introduction into the boiler. Furthermore, there is a vast difference in the character of different waters, consequently each case must be studied and worked out by itself and the proper remedy prescribed. It is evident, therefore, that the elimination of impurities in the boiler-feed water and making it suitable for steaming purposes is one of the most difficult problems that confronts the engineer.

The various impurities in all waters may be divided into two general classes; namely, insoluble impurities, which can be removed by sedimentation or by filtration; and soluble impurities, which cannot be removed unless they are first thrown into suspension and then taken out by sedimentation or by filtration. While the insoluble or suspended impurities are a factor in considering the suitability of a water for boiler-feed purposes, nevertheless, they are of minor importance and can be taken out so easily that they need not here be further considered.

The most common of the soluble impurities, or those held in solution, are the following:

Magnesium sulphate, which is quite common in many waters and is extremely soluble. By itself it will not form scale, but it is easily broken up by lime salts from which scale is formed.

Calcium sulphate, also quite common in all natural

water supplies and which forms the hardest boiler scale. Furthermore, this salt will act as a cement, causing a hard scale formation with salts which ordinarily would form only a soft scale or sludge.

Calcium carbonate, which is only slightly soluble in pure water, but in the presence of carbonic acid dissolves in the water, forming bicarbonate of lime, which is soluble. Alone, however, bicarbonate of lime will not make a hard scale, but when present with other substances, which cement it, a hard scale is apt to result.

Magnesium carbonate is more soluble than calcium carbonate. It is usually found in water as bicarbonate of magnesia and has nearly all the characteristics of calcium bicarbonate.

Calcium chloride, which is very soluble and sometimes found in natural waters. In the absence of other scale-forming salts it is not injurious unless highly concentrated. After concentration in the boiler, however, it becomes dissociated and liberates hydrochloric acid, which, of course, is highly corrosive.

Magnesium chloride, a very objectionable salt because it both forms a scale and liberates hydrochloric acid.

Calcium nitrate, having practically the same characteristics as calcium chloride. Waters containing this salt are, however, comparatively rare.

Magnesium nitrate, usually present in only very small quantities and characteristically similar to magnesium chloride.

Sulphates of iron and alumina may be found in waters contaminated with the waste from galvanizing works or with mine drainage and, because of their dissociation by heat, sulphuric acid is given off and the iron or alumina precipitated as scale or sludge. These substances are very injurious in a boiler and cause corrosion the same as free sulphuric acid. The oxides of iron and alumina, on the other hand, while usually present in small quantities in nearly all waters, have but a slight bearing on scale formation.

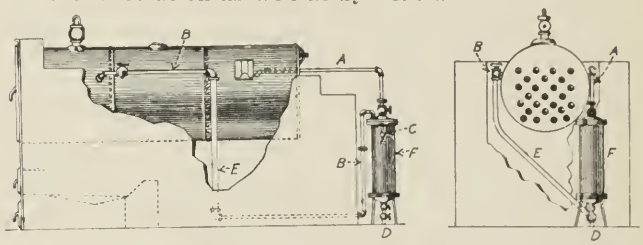
Sodium salts, that is, the sulphates, carbonates, nitrates and chlorides, are all neutral, do not form scale and are non-corrosive, consequently they are not objectionable unless present in large quantities. Silica may also be found in nearly all waters and, while it is a scale-forming substance, yet it is present only in such small quantities that it usually need not be considered.

In addition to all of the foregoing there is always some free carbonic acid in all natural, or raw, water which, of course, promotes corrosion in the boiler. This acid also holds in solution the calcium and magnesium carbonates. Also, if the water contains drainage from mines or galvanizing plants, there is sulphuric acid present in its free state which is extremely objectionable because it attacks the metal in the boiler immediately. This action forms iron sulphate which the heat in the boiler decomposes, resulting again in free sulphuric acid and iron hydrate. The liberated acid again attacks the metal and so goes through repeated cycles indefinitely. Since this acid is not volatile, its amount in the boiler is naturally increased continually by the quantity introduced with the feed water, so that it can easily be seen how the corrosive action multiplies in intensity and in direct ratio, as it were, with the concentration in the boiler.

The soluble-scale forming matter may also be divided into two general classes, those causing temporary hardness of the water and those causing permanent hardness. The former consists of the carbonates of lime, magnesia and iron. Their precipitation begins at temperatures approaching 212 deg. Fahr. and they can be entirely removed by boiling the water at atmospheric pressure for a short time. Permanent hardness is due to the sulphates, chlorides, and nitrates of lime, magnesia and iron which will not be precipitated at temperatures below the boiling point, consequently their removal together with that of the acids constitutes the real problem in water purification.

From the fact that a natural, or raw, water can contain such a large variety of impurities in varying quantities, it is evident that the problem is rather complicated and that each specific case must receive individual attention if the results are to be satisfactory. It should also be remembered that the characteristics of the impurities change under the different pressures and temperatures in the boiler and that their scale-forming properties are largely interdependent. Furthermore, the amount of scale formed does not always bear a direct relation to the amount of impurities in the feed water, but depends on the type of boiler and the rate at which it is operated as well as upon the nature of the impurities. Concentration in the boiler is another factor that enters into the question, since none but volatile matter passes out with the steam, consequently the non-volatile impurities gradually accumulate, forming varying quantitative relations with each other.

Although the scale formed in a boiler is the direct result of impurities in the water, yet an analysis of this scale is of practically no value in determining the character of the water from which the scale was deposited because of the fact that the scale is the precipitation resulting from reactions between some of the substances in solution as well as by heat and concentration.



APPARATUS FOR SODA ASH TREATMENT

Therefore, the original character of the impurities in the water is not always apparent in the scale.

In order to decide on the suitability of a water, or on its treatment for boiler feed purposes, it is essential that a careful and accurate analysis of it be made. This should be done by a chemist who makes a specialty of such analyses and who is thoroughly familiar with the characteristics of the water in relation to boiler operation. Unfortunately, however, this is not always done; or the remedy prescribed as a result of such analysis is not carried out. This is evidenced by the fact that scale is still prevalent in many boilers and that the manufacturers of tube cleaners, etc., are still busy making mechanical scale removers. Moreover, there are many compounds as well as mechanical contrivances on the market that are guaranteed (?) to prevent scale formation in the boiler, no matter what kind of water is used. Some of these may be efficacious under certain conditions and with certain waters, but as a general cure-all they are an absolute failure.

Use of Boiler Compounds

One quite prevalent method of preventing scale, or rather trying to, is by the use of boiler compounds, some of which act chemically and others mechanically. Kerosene and crude oil are also sometimes used, but to a much less extent. Graphite is the most common material which acts mechanically and its purpose is to give the interior of the boiler a thin coating which will prevent the adherence of the scale-forming matter to the shell and tubes. It seems, however, that its efficacy under all conditions and for all kinds of water is a matter for honest debate. The compounds which act chemi-

cally usually consist of sodium carbonate in combination with some organic acid such as acetic or tannic.

While it is true that in certain specific instances the use of a boiler compound has prevented, or at least reduced, the formation of scale, nevertheless, in order to obtain such results it is essential that the quality and quantity of the compound should be specially adapted to the particular water in which it is used. This makes it extremely difficult to use a compound successfully because of the variable quality of feed waters and the large variation in the amount of water fed into the boiler. As a rule, however, boiler compounds are quite effective in overcoming corrosion because they are usually alkaline in nature and, therefore, neutralize the acids. On the other hand, extreme care should be exercised in using a compound for this purpose because many of them contain corroding agents and consequently are in themselves the cause of corrosion.

Aside from acting as a neutralizing agent for acids, the only function of a compound is to change the nature of the precipitate from one which adheres to the surfaces of the boiler to one which will be carried in suspension in the water. The result is a muddy, insoluble mass made up from the impurities already in the water plus the ingredients in the compound itself. This naturally increases the density of the water and consequently its boiling point is raised because of the fact that the soluble impurities are constantly increased by the concentration resulting from the evaporation of only pure water. This action makes of the boiler simply a catch-all or accumulator for the foreign matter. Furthermore, this accumulation of sludge cannot be entirely removed by blowing off, therefore frequent washing out becomes a necessity. In brief, it may be said that the use of boiler compounds is an attack on the result rather than on the cause and as such should only be followed when no better means of treating the water is practicable.

Soda Ash Treatment Within the Boiler

There is another method of treating boiler feed water on the market which is similar in principle to the use of boiler compounds in that the water is treated after its introduction into the boiler. This system goes a step further, however, and employs a filter to remove from the boiler water all the impurities held in suspension. In other words, it is a combination of chemical treatment and mechanical filtration. Reference to Figs. 1 and 2 will show the principle by which this is accomplished.

Soda ash is first introduced into the boiler in sufficient quantities to throw into suspension all the soluble impurities contained in the water. The water containing this suspended foreign matter is then drawn off through the pipe A and carried down through the center of the filter F which has a collecting space at the bottom. It is then forced upward through a crushed granite filtering medium and returned to the boiler as pure water through the pipes B and E. The Pipe E, which acts as a circulating pipe also, is considerably larger than any of the other connections and is so located in the boiler furnace as to be exposed to the greatest heat, the idea being that the circulation set up in this manner will cause sufficient suction through the apparatus to draw off the suspended matter from all parts of the boiler. To clean the filter the blow-off valves D are opened and the valve on the "draw-off" pipe A is closed. This releases the steam pressure through the return pipes B and E and reverses the flow through the filter, thus removing the collected sludge, etc., from the filter. C is a small vent to free the filter from steam after blowing out. The location of the connections of pipes A and B to the boiler are of no special importance except that they must be below the flue level so as to be entirely submerged.

It would seem that a considerable loss of heat would be entailed by the use of this system of water purification, both from radiation and from the loss of the heated water blown out through the blow-off valves. In fact, a loss by radiation is practically admitted by the manufacturers of the apparatus because the assertion is made that a lower temperature in the filter materially assists precipitation, which is completely effected in the upward movement of the water through the filtering medium. That a loss results from blowing out some of the heated water every time the filter is cleaned is, of course, self evident. Furthermore, while this apparatus, if it performs the functions intended, will prevent concentration in the boiler, yet the same objections to it might be raised that apply to the use of boiler compounds; namely, it is not good practice to do the purifying within the boiler itself because of its interference with the business of making steam. Any advantages it might have lie in its cheapness, small floor space required, low operating cost, etc.

A Physiochemical Action

Perhaps the most remarkable and startling novelty in the way of a feed water purifier is what is called a "Luminator." It consists simply of an aluminum plate of specific dimensions and having corrugations thereon of a particular size, both of which are determined by the character of the water to be treated. The treatment is merely allowing the water to run over this plate. It seems that a current of electricity is induced by the passage of the water at certain speeds over the plate and, the water being negative and the plate positive, ionization of the salts takes place. These do not take a crystalline form but become amorphous. It seems there is also another action which takes place; namely, aluminum is by friction and electrical action abraded from the surface of the plate as a colloid, which, after a period of time, also undergoes a change in the water. These remarkable changes are all brought about without the aid of chemicals of any kind, the whole process being called purely "physiochemical."

Professor Donnon at the Liverpool University, England, has investigated this process, it seems, and has found that aluminum hydroxide was not present to any appreciable extent in the water treated by this method; but he did find that the aluminum was in a collodial form mixed with hydroxide and remained so for several days after treatment. Reports further seem to indicate that the best results are obtained when the so-called "luminator" is facing either north or south and is exposed to direct light! Also that if shut in completely from light and air it becomes almost inoperative. The professor assumes that the earth's magnetism has some effect on the operation of the plate and that if its plane is set so that the earth's magnetic field crosses it there will be produced a small electromotive force at right angles to the grooves of the plate as the water flows down, resulting in a slight electrolytic action and thus precipitating aluminum hydroxide in the solution. He also says that the local electricity, together with a certain amount of chemical action, due to the heterogeneous nature of the metal, are sufficient to explain the surprising and hitherto unknown disintegration of the aluminum. That this explanation is quite clear is more than doubtful.

The foregoing would indicate that boiler troubles resulting from scale formation could be overcome by the simple expedient of installing an aluminum plate and passing the feed water over it. There must be, however, certain limitations to the efficacy of this method of water purification. For example, water containing ferrous sulphate, or large quantities of iron in any form, are

not susceptible to such treatment because of the continual deposit of iron on the plate.

Likewise, any acid in the water will not be neutralized, such water requiring a preliminary treatment by passing it over marble or chalk in order to get the desired result. Furthermore, if the "luminator" is at some distance from the boiler it is necessary that the water mains, etc., be coated with a non-conducting composition, such as bituminous varnish, and that the water reach the boiler as soon after treatment as possible. The statement is also made that where the apparatus is used continuously night and day it is advisable to give it a rest of one day per week, otherwise the plate may become "polarized." It is rather difficult to reconcile this statement with the one stating that the plate must be exposed to light to be effective. If the latter is true how can it be used both day and night?

Assuming that this aluminum plate will do the things that are claimed for it, the question is: What becomes of the various impurities contained in the water? In reply to this we are told that the various salts in the raw water before and after treatment show, upon analysis, the same chemical composition; that the sulphates and carbonates of calcium, as well as the magnesium salts, remain as before; and that only a physical change takes place. In a boiler this change is supposed to take place immediately, thus preventing the salts from again going back from the amorphous to the crystalline form, consequently they are deposited as a powder.

This supposed action of the "luminator" and the consequent results obtained therefrom may, perhaps, be quite clear to the inventors, but to the writer it certainly savors of mystery and magic. In other words, this "luminous" treatment of water is not very illuminating and the claims supporting it are far from convincing. At all events there will no doubt be considerable "missionary" work required before it receives anything but the most skeptical consideration.

Water Heater-Purifiers

One of the common methods of attacking the problem of scale formation in the boiler is by pre-heating the feed water. This method is based on the well-known fact that raising the temperature of water reduces the solubility of some of the salts in solution. The apparatus used for this purpose is the "feed-water heater and purifier," and is designed to receive the deposition of the scale-forming substance instead of letting them enter the boiler itself. That it will fulfill this purpose to some extent is unquestionably true, but whether it completely solves the problem or not is rather doubtful.

There are two kinds of heater-purifiers on the market, both of which are supposed to intercept the impurities in the water. One is the open or exhaust steam heater into which only exhaust or low-pressure steam is introduced to heat the water, and the other is the closed or live-steam heater in which steam at boiler pressure is used. In the first, of course, the temperature of the water cannot be raised to more than 212 deg. Fahr., the boiling point of water at atmospheric pressure. It is also obvious that in this type of heater only the temporary hardness of the water will be effected and that only partially, because precipitation is a gradual rather than an instantaneous process and the length of time the water is usually allowed to remain in the heater is not sufficient to make the precipitation complete. To overcome this difficulty the size of the apparatus has lately been increased so as to allow the water to remain longer; and in some instances softening reagents have been introduced and a filtering device attached. These steps taken by the manufacturers are an indication that the old type of open, exhaust heater-purifier does not fully meet the requirements.

The closed type, or live-steam apparatus, on the other hand, will remove practically all of the temporary hardness but not all of the permanent hardness. While it carries practically the same pressure and temperature as the boiler, yet to precipitate calcium sulphate, for example, a certain amount of concentration is necessary in spite of the general assumption that this salt is insoluble at temperatures above 300 deg. Fahr.

The real function of a heater is to heat the feed water and as such both types are very successful. As a purifier, however, it does not quite come up to requirements, although it must be given credit for doing some good. In the same sense that a feed-water heater is also a purifier so might the boiler be called a purifier because scale deposits in both. Aside from heating the water, the advantage in the heater is that this deposit is more easily removed than from the boiler, provided, however, it entirely purifies the water so there will be no deposition at all in the boiler.

Chemical Water Softening Systems

Any method or apparatus for softening and purifying water in a satisfactory manner must be such that the acid contained will either be eliminated or neutralized; the permanent hardness removed and any remaining scale-forming substances reduced to a negligible quantity. It must also produce a clear effluent. If these results are not obtained, then the method employed is either wrong in theory or application, or the apparatus is faulty in design or operation or both. Of course, to properly treat water is a rather delicate process, more so perhaps than might be generally believed. This is because of the small relation the amount of impurities, which have to be removed, bears to the volume of water to be treated. Therefore, to get results, an accurate analysis of the water is of prime importance for determining the treatment and the apparatus required.

Without doubt the most satisfactory and efficient manner of treating feed water is by means of proper reagents in exact quantities to react with the impurities, followed by the complete clarification of the water by sedimentation and filtration. The apparatus on the market that operates on this principle is commonly called a "water softening and purifying system." There are two types of this apparatus, one called the continuous and the other called the intermittent. Either one will produce good results if given proper attention.

In the continuous system the reagents are introduced by proportional feed devices, usually actuated by the water entering the system. The water enters either at the top or bottom and flows out by displacement at the same rate at which it enters. An adjustment must, therefore, be made in the quantity of reagents introduced in order to meet every variation or change in the water. Unless this matter of adjustment is watched carefully there probably will be times when the water is overtreated and other times when it is undertreated.

In the intermittent type, on the other hand, the water is always treated in measured quantities, and the exact quantities of reagents required are weighed out; therefore, any water can be treated most accurately, no matter how it may vary in quality or quantity. But, as compared with the continuous system, it requires much more ground area, more expansive foundations, and possibly a little more labor to operate.

However, it is not the intention to weigh the advantages, or otherwise, of the one system against those of the other, because, as said before, if properly attended to, either one will give results, as attested by the fact that there are a great many of both kinds not only in use but also are being sold at the present time.

As a general rule the reduction of the scale-forming impurities to 5 grains per United States gallon and the

elimination of the acids is considered good practice. There are, however, cases where it has been found necessary to reduce the scale-forming substances to less than 3 grains to prevent scale, and others where good results are obtained with as high as 6 to 7 grains. It is impossible, of course, to remove all of the substances, as calcium carbonate and magnesium hydrate are slightly soluble at all times. Nor is it possible to take out any sodium salts except by distillation, because they are all soluble and no chemical treatment will throw them into suspension. In properly treated water, however, they do no harm to the boiler as they are neutral, non-corrosive, and non-scaling.

The reagents commonly used in these water-softening systems are lime and soda ash, although other substances are sometimes used, depending upon the nature of the water. The cost of purifying will, of course, depend upon the amount of reagents required, for it is readily understood that it will require more chemicals to remove 30 grains of some impurity than it will to remove 10 grains. Almost any expense, however, incidental to the proper softening and purifying of water for boiler feed purposes is more than offset by the savings that result.

In conclusion it might be observed that the limit of possible economy is much more distant in the boiler house than in the engine room and that the first essential in economy of boiler operation is that the water should be of a quality which will permit of the utilization of the greatest number of heat units in the fuel, at a minimum cost of boiler maintenance. In many steam plants may be found the most improved design of boilers, with mechanical stokers, stack dampers, feed-water regulators, feed-water heaters or economizers, and no doubt the most economical prime mover obtainable in the engine room; but the matter of pure water is often totally neglected.

Electric Smoke and Fume Precipitation Before the American Institute of Electrical Engineers

The morning session of Friday, February 19, 1915, of the Midwinter Convention of the American Institute of Electrical Engineers was devoted to a symposium of papers on electrostatic fume and smoke precipitation. The large lecture hall of the United Engineering Societies Building was filled. Many members of the American Institute of Mining Engineers were present, following a cordial invitation extended to them. President P. M. Lincoln of the American Institute of Electrical Engineers presided.

The first paper was presented by Dr. Frederick G. Cottrell who gave a very full and detailed historical sketch of electrostatic fume precipitation, starting with a German text book note of 1824, but dealing naturally in greater detail with the work of Sir Oliver Lodge, and then sketching his work which led Cottrell, jointly with O'Neill, Heller and Miller to the formation of the Research Corporation (see our February issue, pages 81 to 84). Work along similar lines, under the direction of the late Robert Kennedy Duncan, of the Mellon Institute, was also noted and Dr. Cottrell was glad to state that a method of coöperation between the Research Corporation and the Mellon Institute had been effected.

The electrostatic precipitation process is naturally suited to solve two problems: first, the precipitation of man-made fumes (smelter fumes, smoke from boiler furnaces and the like), and second, the precipitation of fog, in the open atmosphere. Sir Oliver Lodge had been specially interested in the second problem. Dr. Cottrell had so far worked only on the first problem, as there was enough trouble to be overcome in its special field and the second problem is better attacked after the first one is solved. Now the San Francisco Exposition seems to offer possibilities of experiments on the second problem and shipping interests have become quite interested in the possibility of using Cottrell apparatus in front of a vessel to dispel fog and prevent accidents.

The second paper of the session was presented by Dr. W. W. Strong, of the Mellon Institute of Industrial Research, on "the theory of the removal of suspended matter from fluids."

The frictional resistance of a small particle moving through a fluid is given by the law of Stokes. Knowing the density and size of the particles and the coefficient of viscosity of the medium, the amount of energy required to remove suspended matter from fluids can be calculated. From the formulas the relative efficiencies of the different methods used to remove suspended matter from gases can be obtained. From these formulas the electrical method is shown to be especially adapted to fine suspended particles or to a mixture of gases that can be selectively ionized. In a practical case of electrical precipitation of smoke it is shown that approximately 4 per cent of the energy of the corona discharge is actually expended in the process of precipitation.

The manner of the distribution of the energy of the corona discharge is discussed. The nature of the corona ionization and the "corona" rays is also briefly described.

The application of the theory of electrical precipitation is given so that it is possible to determine the best working conditions for precipitating a given kind of suspended matter from a given fluid. The theory also indicates the limits of usefulness of the method of electrical precipitation.

Dr. Strong showed at the conclusion of his paper a number of lantern slides and moving pictures.

Professor A. F. Nesbit, of the University of Pittsburgh, followed with a paper on "the theoretical and experimental consideration of electrical precipitation," also illustrated by lantern slides.

Mr. Linn Bradley presented the last paper of the session on "practical applications of electrical precipitation and progress of the Research Corporation."

The technical and financial progress made by the Research Corporation since its organization in 1912 is given, and several plants are described. Voltages, electrode spacings, power consumption, etc., are given for several installations. Mention is made of a number of improvements in the electrical apparatus and means for its control. Progress has been made towards standardization of apparatus for this work.

The paper is illustrated with reproductions from photographs of installations in various stages of operation. Curves and charts show the peculiar character of the circuit, the method of obtaining data to be used in designing treaters and of conducting tests. Alternating current of 250,000 volts has been rectified and used for precipitating particles from gases. Fumes have been separated into fractions by means of temperature control and the electric process.

A selected bibliography is included. The statement is made that within three years time the original capital of $10,100 has been paid back to the stockholders, and that a fund of over $150,000 has been accumulated from the corporation's work, to be used for scientific research.

After the conclusion of the paper Mr. Bradley showed lantern slides and moving pictures of Cottrell plants in actual practice and finally demonstrated experimentally the Cottrell process for fume precipitation. The demonstration was very successful, the smoke being instantaneously stopped by closing the circuit of the Cottrell apparatus, and appearing again quickly when the circuit was opened.

In the discussions which followed Messrs. Franklin, Bradley, Dushman, Nesbit and Job participated. Of particular interest was the statement of Dr. Dushman of the General Electric Company that a very simple rectifier had been evolved on Dr. Langmuir's principle that the electron emission from a hot filament in a high vacuum is unidirectional. Professor Nesbit confirmed that this rectifier type, which is of very small size, works very well for smoke precipitation.

Filling the Blast Furnace

BY J. E. JOHNSON, JR.

This is the most important single operation of the whole blast furnace process. The details by which it was carried on in early years are quite unknown to me. The earliest system of which I have knowledge consisted in throwing into the open furnace top the ore and limestone from large wheelbarrows, while the charcoal was thrown in from baskets made for that purpose, these baskets being elliptical in shape, about 4 ft. long, by 2½ ft. wide by 1 ft. deep, with hand-holds at each end. When mineral fuel was used it also was handled in wheelbarrows and even before the introduction of the closed top the use of "filling barrows" became almost universal except at charcoal furnaces. These barrows

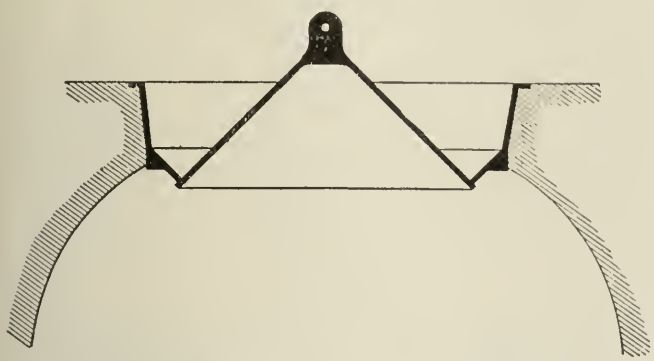


FIG. 1—SINGLE BELL AND HOPPER

(Distributes the charge in a ring next to the lining.)

are the two-wheeled type illustrated in the second article of this series.

The first method adopted for closing the top of the blast furnace was the one which has remained in use practically ever since. The apparatus is known as the "bell and hopper." In its simplest form it is illustrated by Fig. 1. It consists of an inverted cone forming a hopper set on, or in modern practice, fastened to the top of the furnace, the opening of the hopper being closed by a cone which sometimes has a rounded top and from its general shape it takes its name, the "bell." The bottom edge of the hopper is turned true in a boring mill as is the lower portion of the surface of the bell, so that they make a good fit. Into the annular space of triangular section formed by these two, the charge is dumped, by tipping forward the barrows on their own axles as a center, and when the bell is lowered the charge slides into the furnace through the annular opening formed.

During the long period in which the furnace approximated to its modern development, and ending with the Duquesne revolution, this method of filling was almost universal. The quantity of labor it involved was well recognized, and many efforts had been made to avoid this by the introduction of mechanical methods of charging. But these so almost universally had a highly detrimental effect on the operation of the furnace that they were in earlier times soon abandoned for the time-tried method universally known as "hand-filling."

It seems at first sight absurd that so simple a matter should be so obscure and should involve such great difficulties. But the spacing of the stock on the bell, the dumping of the barrows at the edge of the hopper, or on the apex of the bell, the size of the charge, and whether the ore and stone should be dumped with the coke, or separately, are all questions which may exercise an influence on the working and economy of the furnace so great as to be literally vital.

This is a field in which we have little or no theory to guide us. Our information comes solely from tedious and expensive empirical methods better described as "trial and error." Our knowledge of what constitutes correct filling comes solely from our observation as to how furnaces work with different types of distribution, and while the whole history of this vast subject abounds in contradictory experiences in the failure of apparatus and methods of operation at one plant which have made a brilliant success at another, and in other facts difficult or impossible to reconcile with one another, certain laws stand out as established by experience so nearly universal that I believe no one will question them.

These laws are: First—The distribution of each kind of stock in the furnace must be symmetrical, about not less than two axes making equal angles with each other. Second—The same proportion of lump and fine must obtain in each of the segments into which the circle of the top is cut by these equally spaced axes. Third—The distribution of fine and coarse material radially must be such as to produce as nearly as possible an equal ascent of gas through each portion of the furnace stack. To these must be added in some cases, if not in all, a fourth—The stock should be distributed not in uniform annular rings around the hopper, but in heaps, equally spaced around it.

In further explanation of the first law it may be said, on the authority of many trials, that it is not sufficient to dump all the stock symmetrically on one diameter of the furnace. No matter how carefully it may be spaced along that diameter, or even if it be dumped by tipping to first one side and then the other of the diameter, the results are unsatisfactory. This is for the reason that the tendency of this method of filling is to make two or perhaps three flat columns of coarse material separated by one or two flat columns of fines as indicated in Figs. 2 and 3, and the gas travels so much more freely through the coarse material that this descends much more rapidly than the fine, and reaches the hearth in an unreduced condition, or perhaps the opposite action takes place, and the gas being unable to penetrate the columns of fine material, does not reduce it adequately, so that it reaches the hearth improperly reduced. At all events one portion of the stock is reduced ahead of the other and the quantity of fuel which must be burned in the hearth is that required by the least reduced portion, which therefore controls the economy of the furnace. We must, therefore, dump the stock on two axes at right angles, three at 60 deg. apart, or four at 45 deg.

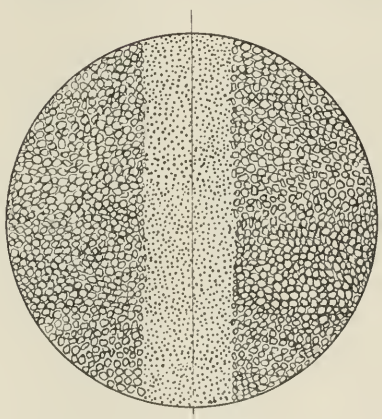


FIG. 2—SKETCH OF DISTRIBUTION OF CHARGE

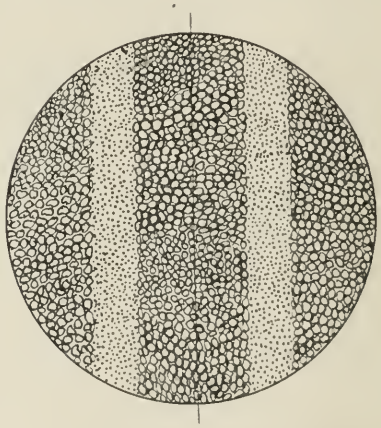


FIG. 3—SKETCH OF DISTRIBUTION OF CHARGE

When hand-filling is used it is quite easy to secure compliance with all four of the laws above stated. By dumping at four or six symmetrically placed points around the hopper, with barrows of the same sort of material, we comply with the first two laws. By the proper adjustment of the size of the bell to the diameter of the stock-line we comply with the third, and the essence of the system involves compliance with the fourth, that is, dumping in heaps symmetrically placed around the bell.

Hand-filling requires that top-fillers be carefully trained to their work, and that some pains be taken to see that they do not dump all the material on the side next to the hoist or otherwise incorrectly. This is a grave temptation to them when the furnace is driving rapidly, and they are pushed to keep up. Their succumbing to this temptation has been the ruination of more than one furnace manager who could not catch them at this trick, or stop them from it; because nothing will more quickly and completely ruin the successful operation of the furnace than filling on one side or irregularly in any way.

Even though the top fillers are well trained and faithful, there remain certain precautions to be taken even with this simple and easy system of filling. The necessity for these arises from two causes. First, the distribution and shape of the four heaps on the bell, if they are dumped consecutively, is not all alike by any means. Second, the charges are practically never made up of a number of barrows of each material divisible by the number of dumping points. That is to say, we may easily have four or six barrows of coke to the charge, to suit the number of dumping point, but this having been determined we must have a number of barrows of different kinds of ore and of limestone, depending upon the weight of the coke charge so established, and these numbers will not commonly, in fact seldom or never, be similarly divisible by four or six as the case may be, if there are twelve barrows in the round.

The lack of symmetry of the different heaps in the hopper when dumped consecutively is due to the fact that the first barrow dumped striking the hopper when it is perfectly empty spreads out laterally in both directions. The second one dumped on the diameter at right angles to it, endeavors to do the same, but the pile which it tends to make is stopped from spreading toward the first barrow dumped by the pile which the latter has formed. Consequently the contents of the second barrow spread freely on one side, but much less freely on the other. Thus the center of gravity of its contents does not lie in its dumping plane, but is deflected away from the first dumping point. The action in the case of the third barrow dumped is exactly the same, it in turn is forced around by the pre-existing heap from the second barrow. When we come to the fourth barrow the space into which it would naturally spread out laterally is cut off on one side by the heap from the first barrow, and on the other side by the heap from the third, with the result that this heap is very generally higher and always much narrower than that from any of the other barrows.

Instead of having a circle divided into four equal parts of 90 deg. each, we have the first of 100 deg., the second of 90 deg., the third of 90 deg., and the fourth of 80 deg., or some similar arrangement. This, of course, lacks very much of being the ideal symmetry which is required not only by theory, but rigorously demanded by the results of practice.

To overcome this lack of symmetry and also that due to the fact that the total number of barrows in a charge is frequently not divisible by the number of dumping points around the hopper, we have a simple means not as universally followed as it should be. This consists in shifting the first point on the bell one space each time. A very easy method of accomplishing this result is to have a number of barrows, one more or one less than an even multiple of the number of barrows in the charge. Then if pains be taken to see that the fillers go round the top always in the same direction, the first barrow dumped on each charge will always be one space away from where it was the last charge On the next, another space, and so on until within a comparatively few charges the circuit has been made, and the first barrow comes back to its starting point. This means that while each individual charge lacks much of symmetry, its initial point is revolved so that each portion of the furnace in turn receives the same treatment, thus producing what is known as "spiral filling," since any given point, such as the dumping point of the first barrow, in the successive charges as they descend through the furnace, makes a series of steps very similar to those of a "spiral" (helical) staircase.

How old this method of filling may be I do not know, it was first called to public attention in a paper before the American Institute of Mining Engineers by W. A. Barrows, then at Sharpsville, Pennsylvania, about ten

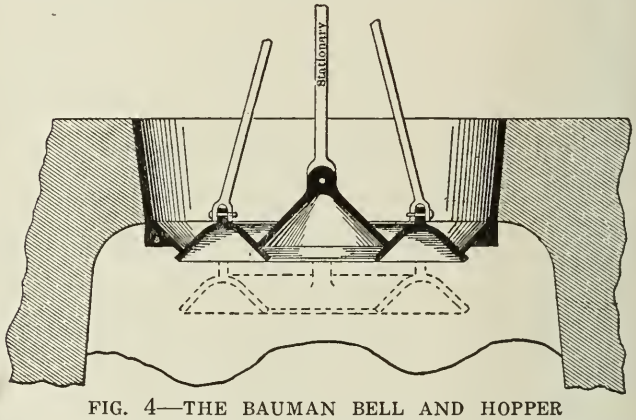


FIG. 4—THE BAUMAN BELL AND HOPPER

(Distributes the charge both in a ring next to the lining and in a heap at the center.)

years ago. On account of the important irregularities in any one charge whose origin I have tried briefly to describe, this or some similar system giving analogous results, should always be used in hand-filling.

When two top-fillers are employed another system can be employed with good results. This consists in having the two men dump their barrows at points immediately opposite one another, and at the same instant. The next time they dump opposite to each other again, but in the case of 4-point dumping this, of course, means, at right angles to the first position. The two pairs of heaps so produced are not similar but each one is similar to its opposite, and by alternating the position for the first dump the series of charges formed are all symmetrical about two axes, although the heaps on one axis are not like those on another, but these are alternated so that in the course of a double charge we even up the inequalities of one charge with those of the next. It is more difficult to secure this sort of filling than it is spiral filling, and this kind should not be used in preference to that except under unusual circumstances.

The size of the charge unit to be used, and whether the coke and ore are to be dumped all at once or separately are questions of operation rather than of construction, and will therefore not be discussed here. But in a general way we may say that coke charges range from six thousand pounds for small furnaces, up to fifteen thousand, and even eighteen thousand pounds on larger ones, while the best practice undoubtedly favors dumping the coke separately from the ore and stone.

Similarly the question of the diameter of the bell which controls the radial distribution of the stock is a question of operation, and not one of construction, since the same construction is used in both cases, with only a relative slight difference in dimensions, and this question can therefore be passed over here.

Many modifications of the bell have been made with the object of securing better distribution and better furnace work. These have sometimes been only changes in dimensions, but many other variations have been used as well. A number of these are shown in Figs. 1, 4, 5, 6, 7, 8, 9, taken from a paper by the late T. F. Whitherbee before the American Institute of Mining Engineers, vol. XXXV, entitled "Special Forms of Blast Furnace Charging Apparatus."

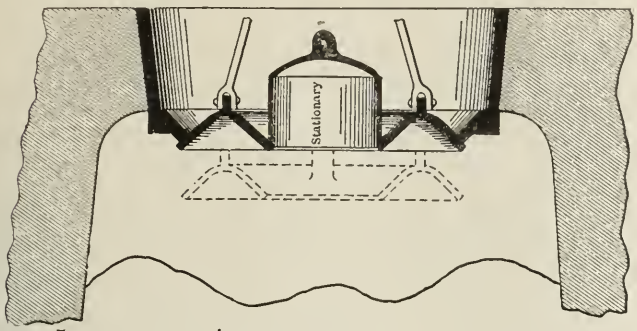


FIG. 5—FIRMSTONE'S MODIFICATION OF THE BAUMAN BELL AND HOPPER

(Distributes the charge both in a ring next to the lining and in a heap at the center.)

Fig. 7 is representative of a number of these, this being the Firmstone modification of the Bauman or double bell. The center of the cone forming the ordinary bell is cut away by an inverted cone having the same angle of slope as the bell, normally 45 deg., and the opening so formed is closed by a (nearly) stationary part commonly called by those who use this type of top, the "plug." This is not quite stationary for the reason that the inner and outer surfaces of the bell must both make a good joint. It would be impossible to maintain an adjustment of the parts which would secure this if both seats were rigid, so the plug is counterweighted until its effective weight is very small and allowed a drop of about a half or three quarters of an inch, which permits it to follow the bell down for this distance on the opening movement, while on the closing movement the bell picks it up and makes the joint on its inner seat first, then reaches its seat on the outer surface or hopper afterwards, carrying with it the plug through the distance the latter dropped in opening.

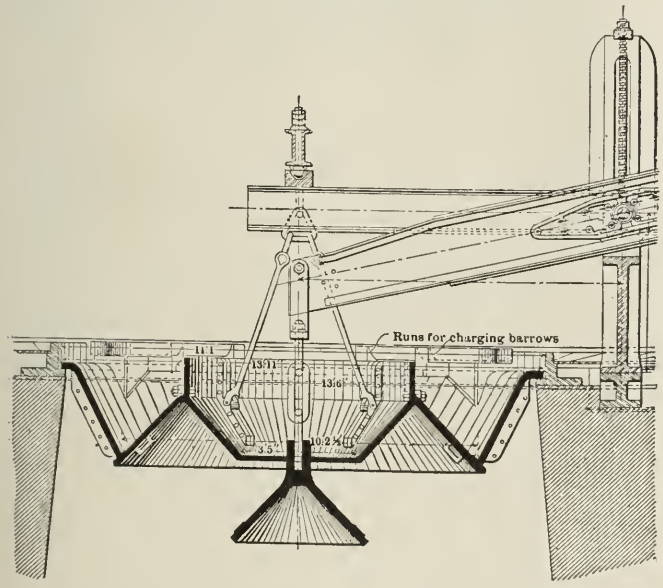


FIG. 6—THE DURHAM BELL AND HOPPER

(Distributes the charge in three ways: 1. In a large ring next to the furnace lining. 2. In a small ring. 3. In both a large and a small ring.)

Fig. 7 differs from the other types shown in that the gas outlet takes place through it, there being no flues in the side walls of the furnace. This secures an absolutely symmetrical distribution of the gas as well as of the stock, and while the former is less important than the latter, it is still very important.

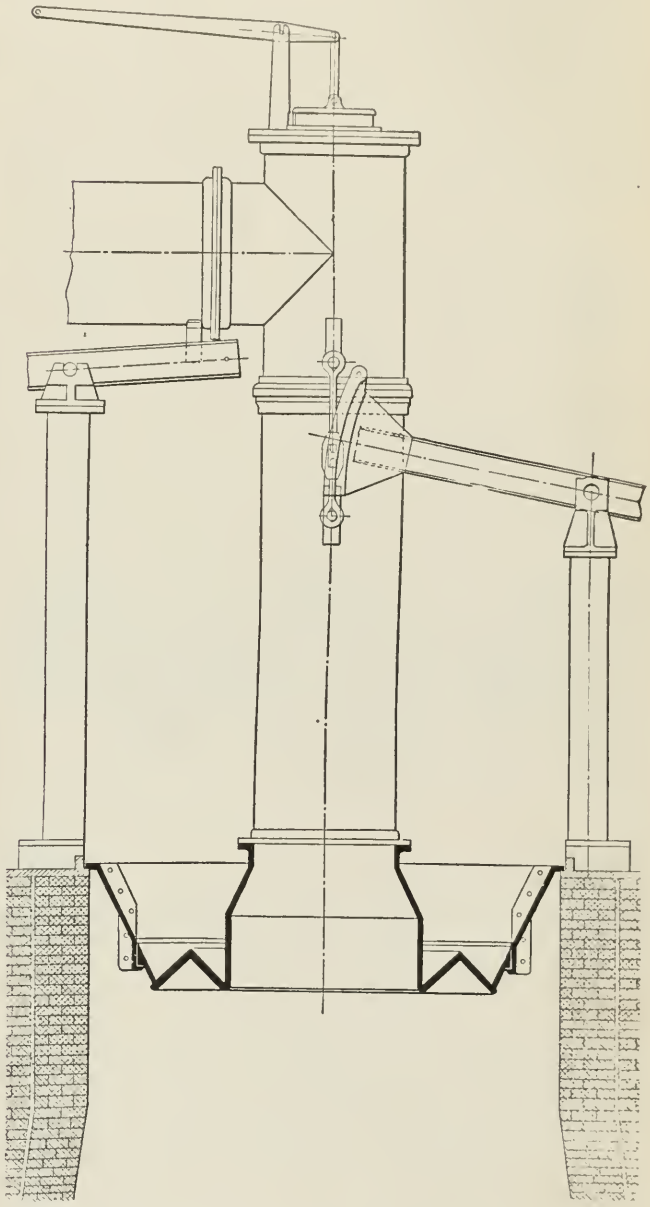


FIG. 7—THE BAUMAN-FIRMSTONE BELL AND HOPPER AT THE LONGDALE

(Distributes the charge both in a ring next to the lining and in a central heap smaller than that shown in Fig. 8.)

Tight joints in the pipe are maintained in spite of the rise and fall of the center plug by ball joints at each end of the horizontal pipe shown broken off at the left hand side of Fig. 7. The ball joint not shown is at the top of the down-comer over the side of the furnace,

while the one in the vertical center pipe is shown at the bottom of the "tee" which forms the junction between the vertical and horizontal pipes. The small amount of vertical movement necessary in the center pipe is taken up by these ball joints without any difficulty. The center pipe, with the plug fastened to it, is suspended from the tee by turn buckles, of which the one on the near side is clearly shown in the illustration.

In this type of top the lever which supports the bell can of course not be located in the center, and is therefore made double and takes hold of the bell at four points. See Fig. 10 which shows the construction used in Fig. 7 also. This type of top was used at the plant of the Longdale Iron Company practically throughout its entire life, and combined with careful hand filling gave excellent results. The great advantage of the double bell over the single is that there are two openings of different diameters, which combined with the reversed

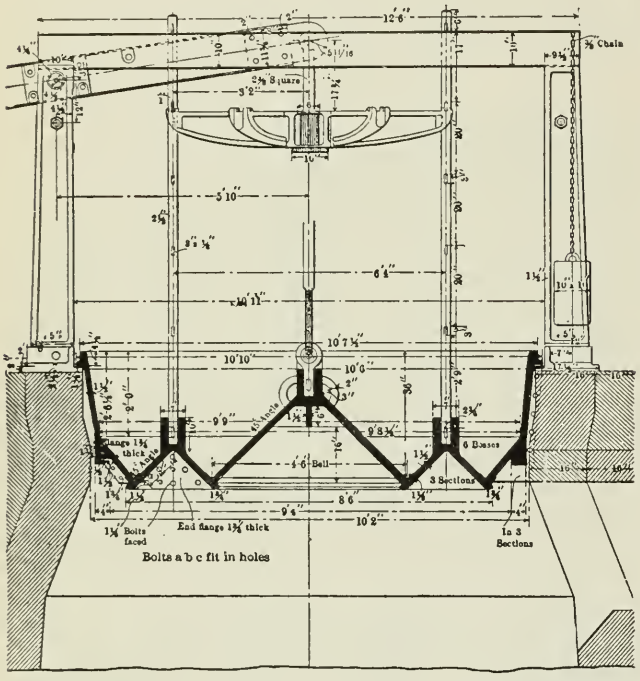


FIG. 8—BAUMAN DOUBLE BELL AND HOPPER AT THE SAUCON FURNACE, HELLERTOWN, PA.

(Distributes the charge both in a ring next to the lining and in a heap at the center.)

slopes inside and outside the bell permit the stock to be distributed more advantageously in the furnace than is possible under certain conditions with the single bell. The latter is confined to a maximum of three circular annular areas of different sizes of material, and may give only two, whereas with the double bell there can be two rings of fines, and three of coarse material, thus permitting a better distribution of the gases over the whole area of the furnace, and exposing the stock to this influence much more effectively.

This top has been used at many other plants beside Longdale, and has been very generally commended by those who have used it, but it is undoubtedly somewhat more complicated than the single bell top, and that, with the extreme difficulty of proving the advantage of one or another method of distribution on the furnace unless one of those under consideration be very bad, has prevented its general adoption.

A still more radical departure from the standard single bell top is the Langen charger in which a central piece like a plug rests in the bottom of the hopper to close it instead of being pulled up from beneath as in the standard type. The "bell," which is still so called in this case, is raised, to open it, instead of being lowered as is the regular bell. Frank Firmstone developed the double Langen charger in which the discharge took place around circles of two different diameters as in the Longdale double bell, but both openings were produced by raising the closing-pieces or bells, first one and then the other. He has described this top as applied by him at the plant of the Glendon Iron Company in the transactions of the American Institute of Mining Engineers, Vol. XIII.

The top is well shown by Fig. 10, reproduced from this paper.

Excellent results were secured with these bells, but more care and skill was necessary in designing and operating them than for the ordinary single bell, and they have never had a wide use in this country, although bells of this type are still extensively used in Germany.

There is one important difference in the conditions under which these tops had their principal use and those which predominate to-day. This is in the size of the ore, which in those times was almost entirely lump com-

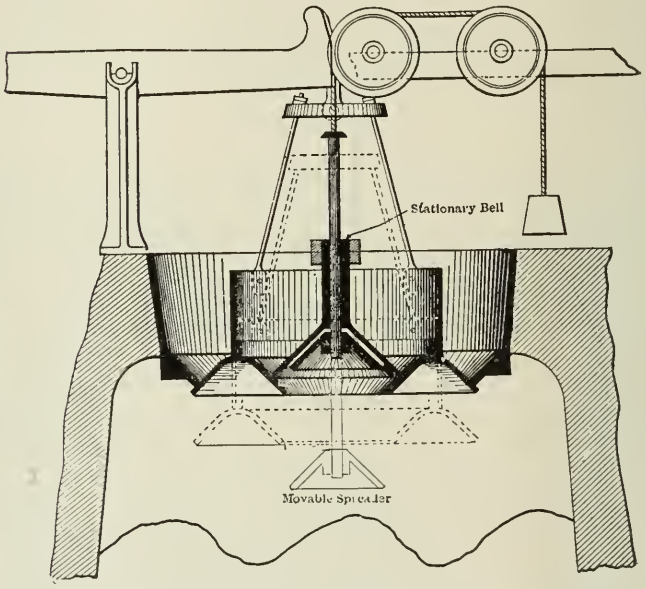


FIG. 9—THE WITHERBEE DOUBLE BELL AND HOPPER

(Five ways of distributing the charge: 1. A ring next to lining. 2. A center heap. 3. A ring next to lining and a center heap. With spreader bell down. 4. A large and a small ring. 5. A small ring.)

parable in size with the fuel, while now the ore is almost exclusively fine.

In order to have the gas travel uniformly through the stock it is very important to have the greater portion of the fines next to the walls since with *material of uniform size* the spaces next to the wall are about twice as great in proportion as they are in the body of the material, because when the high points of the individual pieces interlock with one another as they do in the mass of the material the interstices are very largely filled, but when the high points come against a flat surface the interstices are preserved complete.

By taking spheres we can determine the amount of interstices under each condition. We find that if there be a layer of spheres of uniform size arranged in close contact in equilateral triangles (the closest possible spacing) with another layer of like spheres resting in the low points of the first as they would arrange themselves naturally, the voids around the half spheres adjacent to the wall would be 65 per cent of their volume while those around the other half (away from the wall) would be 35 per cent.

This shows quantitatively the effect of the wall in

increasing the interstics under conditions in which we can calculate it, and the general nature of the effect is the same in irregular materials.

It is an old tradition in the business that the fine material must be put against the walls and it is obvious from these considerations that this is correct, and therefore the fines, that is the ore in modern practice, must go largely against the wall if we are to avoid excessive flow of gas there. Therefore we need now a single bell of rather large diameter in proportion to the stock line, but in the days of lump ores it was possible to carry this to an extreme and to have the charge column too open through the center and an excess flow of gas there, so it was desirable under those conditions to dump part of the charge in the center so that some fines would reach that part and help to obstruct it.

Mechanical Charging

Many attempts had been made to use the skip for filling purposes as well as many other mechanical appliances which would at least permit the elimination of the top fillers, usually the hardest worked, and always the ones with the greatest capacity of doing harm by improper dumping. But the results of all these early attempts had been excessively unsatisfactory because the work of the furnace was so much poorer that increased fuel consumption, diminished output, lowered quality of product, and reduced life of lining amounted

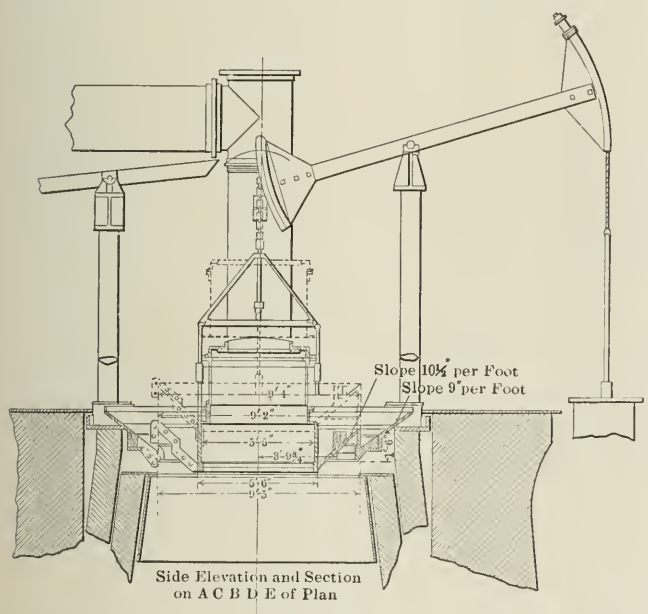


FIG. 10—DOUBLE LANGEN CHARGER DESIGNED BY FRANK FIRMSTONE FOR THE GLENDEN IRON WORKS

to very many times more on the debit side of the ledger than the slight saving of labor on the credit side.

In that early day it is well to note that the barrows were generally filled by hand shoveling, furnace operators having been exceedingly slow in realizing the value of bins. The idea that the greater portion of the work of the bottom fillers could not be reduced explains why the early attempts at mechanical filling were directed mainly at eliminating the top fillers. This made the saving relatively small, while the loss due to bad distribution may easily be, in fact generally is, of enormous proportions, and may quickly convert a profitable into a bankrupt concern.

With the rapid increase in output which took place in the early nineties and culminated in the Duquesne revolution, the difficulties of filling the furnace became more and more serious. In addition to the vast difficulty of training and keeping crews of the size necessary to do this work by hand, and of supervising their performance of it to secure good furnace operation, it became almost a physical impossibility to handle the number of barrows required, and get them on and off of the hoist platform at the top and bottom of its travel, even though the operation was kept up at the highest possible pressure for twenty-four hours a day and practically without intermission. If any interruption occurred it became more and more difficult to "catch" the furnace after the stock line had gone down below the proper level; the fillers were kept almost up to their maximum speed to keep even with it under normal conditions and obviously had to make a stern chase in order to overcome any lead that it might get by an interruption in the charging.

The great expense of this method also became more and more obvious as the number of men required increased, and looking at the matter from the financial point of view it was well worth while to make an investment which would eliminate the labor of sixty men, while the same investment to eliminate the labor of only twenty might be a very poor one. In other words the annual cost was high enough to pay fixed charges on a heavy plant investment if a suitable means could be found for filling the furnace mechanically.

The necessities of the case were so great that renewed and more extensive efforts were made to solve the problem of stock distribution mechanically, and in the middle nineties a number of designs were brought out by various engineers for the accomplishment of this purpose.

For a long time after the introduction of the bell and hopper to close the top of the furnace no effort was made to prevent the escape of the gas during the time that the bell was open for the introduction of the stock, but with the increased appreciation of the value of this excellent fuel it became more desirable to prevent even this waste, amounting to some 3 to 10 per cent of the total gas produced, and for this purpose a secondary valve or seal was sometimes provided which was closed before the main bell was opened, and opened only after the main bell was closed.

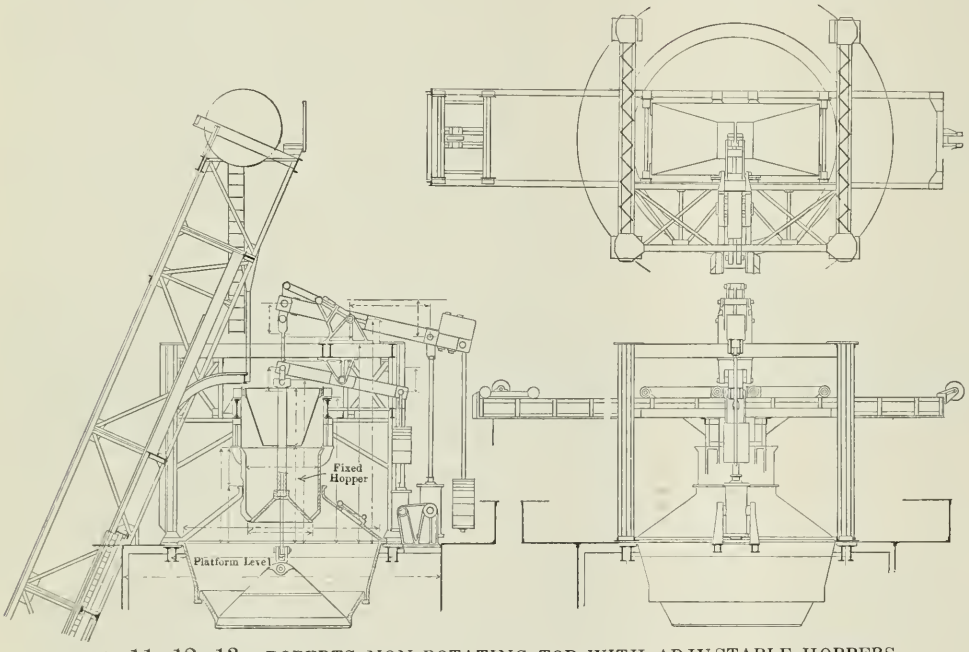
One of the earliest forms of this apparatus consisted of a huge iron lid like a pot lid, which was lowered down onto the top of the hopper before the bell was opened, and raised again after the bell was closed.

The introduction of mechanical filling made the closing of the furnace top while dumping the main bell easier and more desirable, and the obvious method of doing this was by the use of an apparatus similar to the air lock used in caisson work which in this case becomes a gas lock in which one valve opens from the outside into the lock, the other opens from the lock into the furnace. The bell having so firmly established itself as the only valve worthy of consideration for closing the furnace top it was perfectly natural that a similar bell should be used for the top valve of the gas lock, and this has become almost universal practice. This was the plan adopted at the Edgar Thompson Works, and in several with other designs.

The development of the double bell type of furnace top made the closed position of the gas seal bell the normal one, and this is greatly to be preferred because with mechanical filling it is possible to operate for a considerable period with the main bell leaking quite freely, if the gas seal be reasonable tight, and if its normal position is closed. But if its normal position be open the leaking gas meeting the air burns up through the throat of the furnace and is likely to do great damage to all the mechanism, even to the extent of softening the rod of the main bell to the point where it can no longer sustain the weight of the latter, and thus causing its loss into the furnace, an accident involving a

frightful amount of hard work and serious financial loss due to a shut down of from twelve to forty-eight hours, according to the style of top and the preparedness of the management for such emergencies.

With the gas seal bell normally closed it cuts off by far the greater portion of the leakage of gas and reduces it to an amount whose combustion can do but little harm. I have run a furnace for several days with a huge piece out of the main bell, because the hood and the gas seal being tight the quantity of gas which could escape was unimportant, but it would be impossible to operate a furnace in this condition if the normal position of the gas seal were open, because such a quantity of gas burning continually would destroy the furnace top completely. Even a much smaller leak is a very serious matter under these conditions; the result is that more work is required to keep the furnace top tight enough for safety, and main bells have to be changed more frequently because only small leaks past them can be tolerated.



FIGS. 11, 12, 13—ROBERTS NON-ROTATING TOP WITH ADJUSTABLE HOPPERS

There are two broad classes of mechanical filling as already described in the second article of this series, which may be broadly called "bucket filling" and "skip filling." There are several varieties of each, though the variations are much more matters of detail than of principle. It will be easier to discuss the points of the bucket system after considering the different types of skip filling, and we will therefore consider the latter first.

The first installation of skip filling commercially successful on a large scale was made at the Edgar Thompson Steel Works, under the supervision of their furnace superintendent, G. C. Kerr (now first vice-president, United States Steel Corporation) and chief engineer, E. E. Slick (now vice-president and general manager, Cambria Steel Company). By careful, painstaking and long-continued experimentation with model tops built exactly to scale, and raw materials crushed and sieved to the same scale, the proportions were found which would give a reasonably uniform and satisfactory distribution of the stock on the bell. A furnace was equipped with a filling apparatus of this design, and it was so successful that except for minor details nothing else has ever since been used at that plant, a record which I think is better than that of almost any other plant in the country since many of them have tried out two or three, and others very many more types of tops.

A typical double-bell furnace top is shown by Figs. 11, 12, and 13, in which the main bell and hopper, the upper or gas seal bell with the hood to connect the seat of the upper bell with the top of the hopper, and all the accessories of the top, including the skip, are well shown.

The upper bell does not need to be nearly so large as the lower one since the diameter of the latter is controlled by the size of the furnace top into which it discharges the charge, but the charge will arrange itself on the main bell in very much the same way irrespective of the size of the upper bell. In fact the small size is of decided advantage, since the nearer the stock enters through a mathematical point in the center of the furnace, the more uniform will its distribution be. If the upper hopper be large, and the stock be delivered into it irregularly by the skips, a greater or less portion of these irregularities will follow through the upper bell down into the lower. The larger the hopper the greater these irregularities may be, and the more completely they follow down onto the main bell, and so into the furnace.

Many plants have adopted what is known as the plain double-bell style of skip filling, but many have had most disastrous results with it, and others after the most careful and conscientious trials to obtain an exact distribution, have reached the conclusion that no form or design of this top is satisfactory because the distance which the materials travel is effected by the size, shape and moisture contents of the different materials and by the velocity of the skip when dumping. What is a perfect distribution on a dry day may be a frightfully bad one during a rain storm if the ore becomes wet, while a good distribution for a coarse coke, free from fine material, may give horrible results with a fine coke much broken up.

Various ingenious schemes have been used to eliminate or control these irregularities, and baffle plates without number have been tried and then discarded for the reason that no matter how good the results might be with one condition, they would infallibly be bad with some change in the conditions, such as was sure to arise within a short time, in ordinary operation. Two of these attempts may be mentioned as showing the lines of endeavor.

The Roberts top designed by Frank C. Roberts of Philadelphia is shown by Figs. 11, 12, 13, showing a central section in the plane of the skip, a front elevation at right angles therewith, and the plan view showing the receiving hopper divided into two triangular pieces, more properly half pyramids, the hopper being a truncated pyramid with its axis in the center line of the furnace, and cut in two in the central plane between the skips. Each of these half hoppers is mounted on four wheels resting on a stationary track at right angles to the plane of the skip. The treads of the wheels are wide, and their flanges set back well inside the line of the track so that the half-hoppers cannot only be moved in and out, but can also be slewed in the horizontal

plane in order to secure that distribution which, under test, seems to give the best results. In other respects the design is similar to that of any other double bell type of top.

The Rowe Top was invented by a young man of that name at a plant where they had suffered greatly from bad distribution. The extreme simplicity of his design enabled it to be applied to the furnace with only a short shut-down, and this application resulted in an immediate and decided improvement in the practice. Unfortunately no drawing of this top is available, but it may be described without much difficulty.

A vertical plate was set up in the hopper immediately under the dumping position of each skip and in its central plane; this served to divide the skip load into two precisely equal halves. To this vertical plate were fastened inclined plates which ran down into the throat of the hopper, one of them sloping from the top corner next the skipway to the opposite bottom corner, and its companion plate on the other side sloping from the top corner farthest from the skipway to the diagonally opposite corner of the vertical plates, so that the planes of the two plates made a letter X, but one line of the X was on one side of the vertical center plate, the other on the opposite side. The bottom ends of the inclined plates were located approximately at the quarter points around the circumference of the throat leading to the bell. Consequently as each skip load came up it was divided into two halves, and those two halves placed on two adjacent quarter points around the throat, similarly when the other skip came up its load was halved and delivered to the other two quarter points.

It is obvious that this action would be but little affected by a change in the velocity of the skip in approaching its dumping position, or by changes in the size, stickiness, etc., of the materials, or at least the changes so produced would be very much smaller than they would if the skips dumped directly and delivered all their material on one side or the other of the throat in accordance with variations in the conditions.

One of the earliest designs was that of M. A. Neeland, at the Ohio works of the National Steel Company, where the throat of the furnace was made quite high, and had set inside of it sloping vanes, roughly like a screw thread, which caused the material to whirl around as it descended through the throat, and as a result of this whirling it was hoped to get a uniform distribution of the stock.

Very much may be done to secure regularity by correct proportioning of the main parts of the apparatus, the location of the skips in their dumping position, the size and shape of the receiving hopper which delivers the material from both skips alike to the throat, and many other details. Each has its effect on the general result, and while many devices such as those mentioned are available, it is far better not to trust to any of these alone but to eliminate the principal irregularities as far as possible by correct design in the first place, even then there will be plenty for the secondary devices to do to secure good distribution.

These irregularities were in several cases within my own knowledge very great. It did not require accurate measurement of the heaps and gaging of the size of the materials in each portion to show this; it was obvious to the most casual observer. The really remarkable feature of the whole situation was that many furnacemen did not recognize the source of their trouble or in some cases did recognize it, but were not allowed to correct it, because to do so would reflect on a design which had been selected by their superior officer.

At one plant using lump ore which I visited about ten years ago I was taken up to the top of the furnace by the stock house foreman. Of the skip load which lay on the upper bell about two-thirds lay on the side next the skipway and consisted of all the finest portion of the load, while the one-third on the opposite side contained all the coarse! The stock house foreman said he thought that gave a very good distribution and when I asked him where the "hot spot" was of which he had told me he pointed down directly in the line of descent of the coarse material.

"Breakage of the Coke"

One of the most important factors in the whole subject of furnace operation was overlooked in the early designs of mechanically filled furnaces. This was the question of breakage of the coke. In some plants this seemed to have been almost totally disregarded. Coke was dumped from hopper cars on high trestles into bins perhaps almost empty, involving a drop of 15 to 25 ft., dropped again from the gate of the bins to the bottom of the scale car or bucket, 6, 8 or 10 ft. more, dropped from the scale car into the skip, a distance equal to the last, from the skip into the receiving hopper some 7 or 8 ft., from the upper bell onto the main bell, about an equal distance again, finally from the main bell onto the stock line, some 8 or 10 ft., if the furnace were full, up to any distance if it were empty.

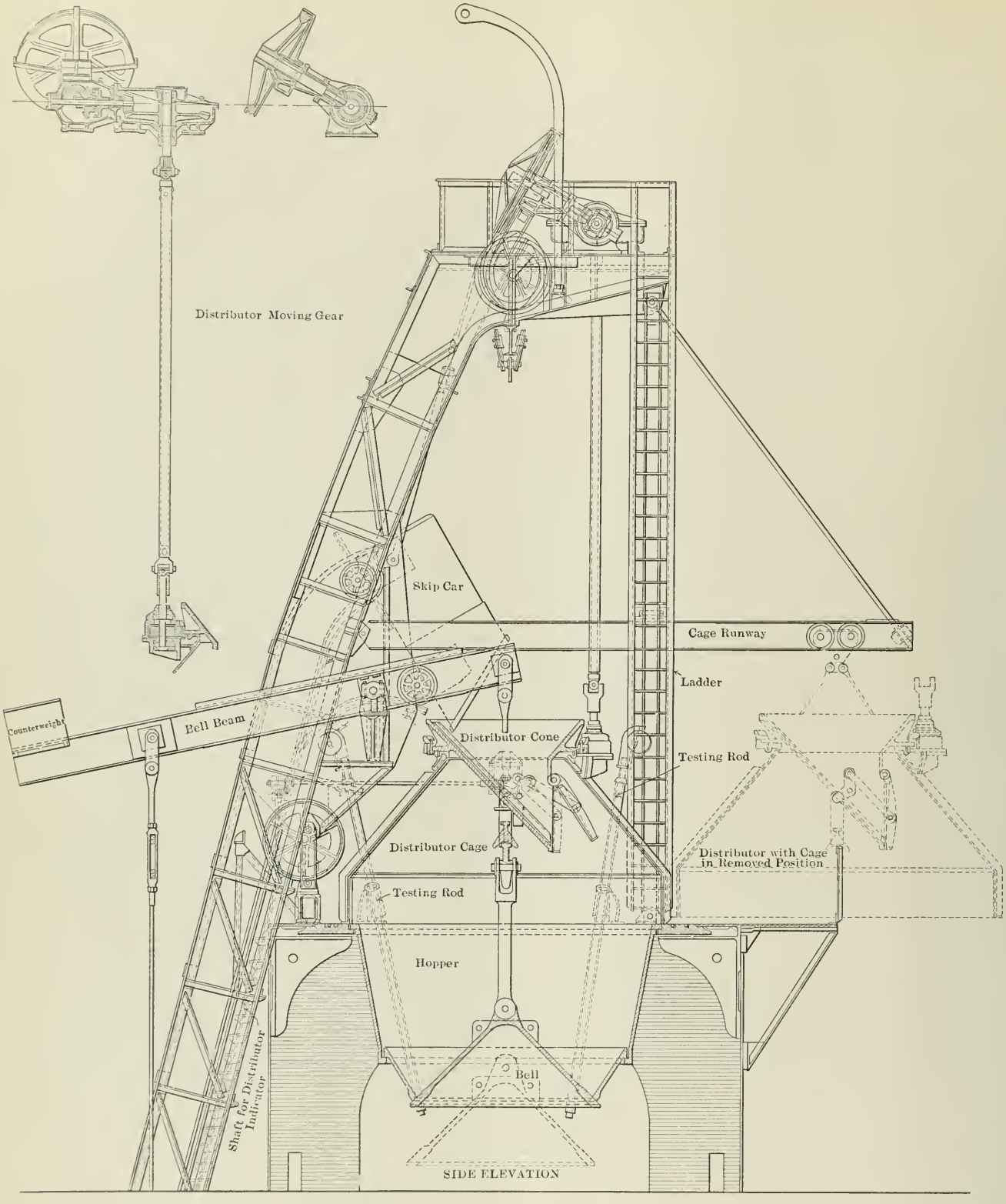
The detrimental action of fine coke in the furnace, and its much reduced fuel value, particularly for heat in the hearth, are well known, and need not be further stressed here though apparently they were overlooked by some of the furnace designers of fifteen years ago. Just how much the coke was broken up, and how much the average size of the individual pieces was reduced, what percentage of detrimental fines were made by this treatment in extreme cases, we shall never know now, perhaps it is just as well that we should not. But the general result was seen in the fuel consumption, and eventually in the cost sheet of many of these plants, while the furnace manager, who in most cases was not responsible for the design, spent many unhappy hours over these conditions for which he had in many cases to take the blame.

It will be noted that with the Duquesne system, presently to be described, the buckets were so designed as to come close up under the bins with only a short spout beneath the gates of the latter. This reduced the drop into the bucket to the minimum, and eliminated two dumpings of the coke as compared with those plants where it was transferred first to the scale car, and then to the skip before reaching the upper bell.

It is altogether possible that this feature had an appreciable influence in bringing about the early success of Duquesne as compared with many of the skip-filled furnaces built soon afterward. Now furnace managers and engineers understand this matter of coke breakage better, and it is recognized that no top should be permitted to give the coke an inch more drop than is absolutely necessary to accomplish the transfer of the stock.

In more recent years the "shatter test" of coke has been invented and attention is paid to the strength of the coke, so that more is known as to the injury done it by any given drop, but with this advance has gone the increasing realization that every unnecessary foot of drop was highly objectionable and could not fail to cause some proportionate share of increased coke breakage.

As a consequence the enormously long throats which were used on some furnaces fifteen years ago have disappeared and one of the major considerations of the present day in regard to any system of filling is its probable effect on the coke. Considering all these important points which were largely or wholly ignored or neglected the only wonder is not that furnaces did bad



FIGS. 14 AND 15—BROWN ROTATING TOP

work in the early day of mechanical filling but that they ran at all.

Rotating Tops

If the location of a given irregularity be rotated through an angle increased by a definite amount at each charge, we shall obviously obtain the equivalent of spiral hand filling and so by evening up over a number of charges the kind of material delivered to each portion of the furnace circumference shall secure the equivalent of uniform filling in each charge. Furnace tops which operate on this principle are called rotating or revolving tops.

There are in use three principal types of rotating tops—the Brown, the Baker and the McKee. All of these are patented and the whole subject has been one of much complexity, not only technical, but to some extent legal. The merits and demerits of the different types of apparatus have been the subject of acute and heated discussion. Each of them has been thrown out of use at one or more plants, and it is therefore necessary to admit that there are objections to all of them.

To state these objections as well as their advantages fearlessly and firmly is the only course open for a satisfactory treatment of this subject; however far short of this object I may come, this at least will be my aim.

The Brown Top

Although I have referred to the persistence of hand-filling as almost universal up to the time of the Duquesne revolution it is a fact that the first reasonably satisfactory apparatus for mechanical charging had been introduced several years before. The skip which dumps by turning nearly upside down, as described in the second article of this series, has been known for a long time. I am told that it was used two hundred years ago in Sweden. An attempt was made to use skip filling by Fayette Brown, the father of the late Alexander E. Brown. It is said that the furnace so filled worked irregularly in the way in which so many such furnaces have done, and the skip was therefore thrown out. In order to secure symmetrical distribution with hand filling it occurred to Fayette Brown to put a cover over the entire hopper with a single opening through it large enough to admit of dumping only one barrow, and at a certain definite location. This cover was revolved about the axis of the furnace by a mechanism driven from the hoist sheaves, so that this opening advanced one dumping space at each revolution. This, of course, forced the top fillers to dump correctly.

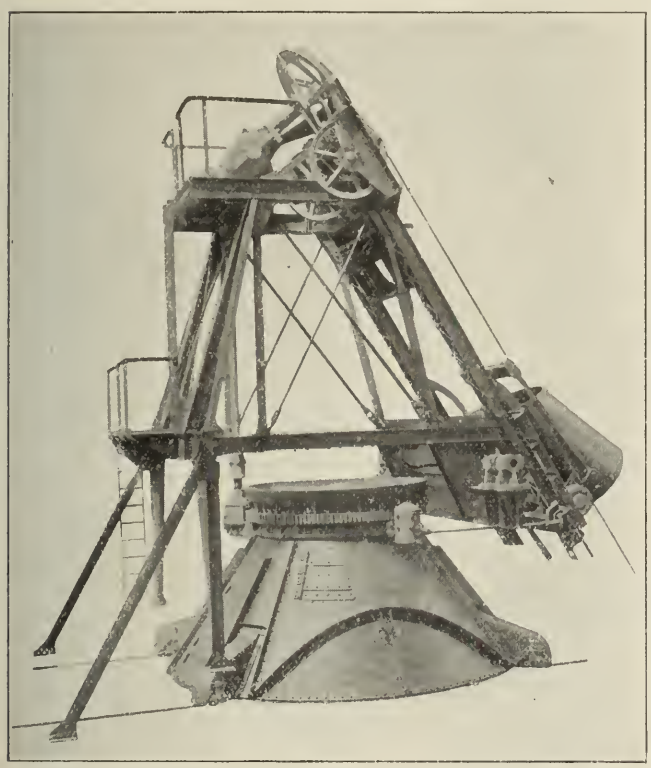


FIG. 16—BROWN TOP REMOVED FROM FURNACE

FIG. 17—RROWN TOP ON FURNACE

Many years later it occurred to Alexander E. Brown to combine this controlled system of dumping with the skip hoist by having the skip deliver into a central hopper with an outlet spout on one side, and revolving this hopper and spout around the vertical axis of the furnace by a mechanism driven from the hoisting sheaves, and this is the essential principle of the "Brown top," at least one of which was in operation several years before the Duquesne revolution, and has, I think, continued in operation from that time to this.

This top as now built is shown by the line drawings, Figs. 14 and 15, and by the photographs, Figs. 16 and 17. At the bottom of the line drawing are shown the bell and hopper; above these, on the top of the furnace proper, is the conical gas seal which acts as a support for the revolving distributor and the gears which drive it. Above the hopper is seen the skip in its dumped position, and at the top the main rope sheave, with the gears through which it drives the vertical shaft descending to the gear box just outside the distributor cone, through which the latter is revolved. The detail of the sheave and the upper gears is shown in Fig. 15.

The gas seal consists of a flap valve on the spout of the receiving hopper whose normal position is open, as shown in full lines in Fig. 14, but which is closed by the first portion of the movement of the main bell, acting through the bell crank shown in dotted lines. This gas seal is not as tight as a bell and is subject to the objection above described, that its normal position is open, so that if the main bell is leaking to a considerable extent the gas can rise through the spout and burn almost without interruption around the upper portion of the top mechanism.

There is a ratchet in the mechanism which drives the hopper when the sheave runs in one direction, but allows it to stand still when the sheave runs in the opposite direction, on the return trip; thus the hopper is rotated a definite amount with each trip of the skip.

At this point Mr. Brown introduced an admirable feature into the design. Instead of having the distributor rotate through an angle commendable with 360 degrees, so that it would always return to the same position at the end of every complete revolution, he designed it to revolve two or three degrees more or less than a quarter of a revolution, so that at the end of four movements it is some ten degrees one side or the other of the point at which it started, and only after many revolutions, representing a great number of charges, does it return to its initial point. This has the great advantage of giving not only each segment, but each fraction of the circumference of the furnace exactly the same treatment, and this is greatly to be preferred to any system which must always use the same starting point,

since in that case any irregularity due to the difference in shape of the first skip load dumped and the last, or the like, is localized in one place and may cause serious trouble, whereas if it went to each point of the circumference in turn it would do no harm.

Any mechanism at the top of the blast furnace has to operate under extremely difficult conditions. It is necessarily surrounded by the dust arising from the different components of the charge which is sharp, gritty, and destructive to the last degree, and is exposed to temperatures not infrequently above any at which lubrication is possible, and if there be a leak of the main bell so that gas escapes at all freely, the apparatus is entirely likely to be subjected to direct flame. These conditions are so severe that they alone have caused the defeat of many tops, and in the early days they undoubtedly caused many mechanical difficulties in the operation of the Brown top.

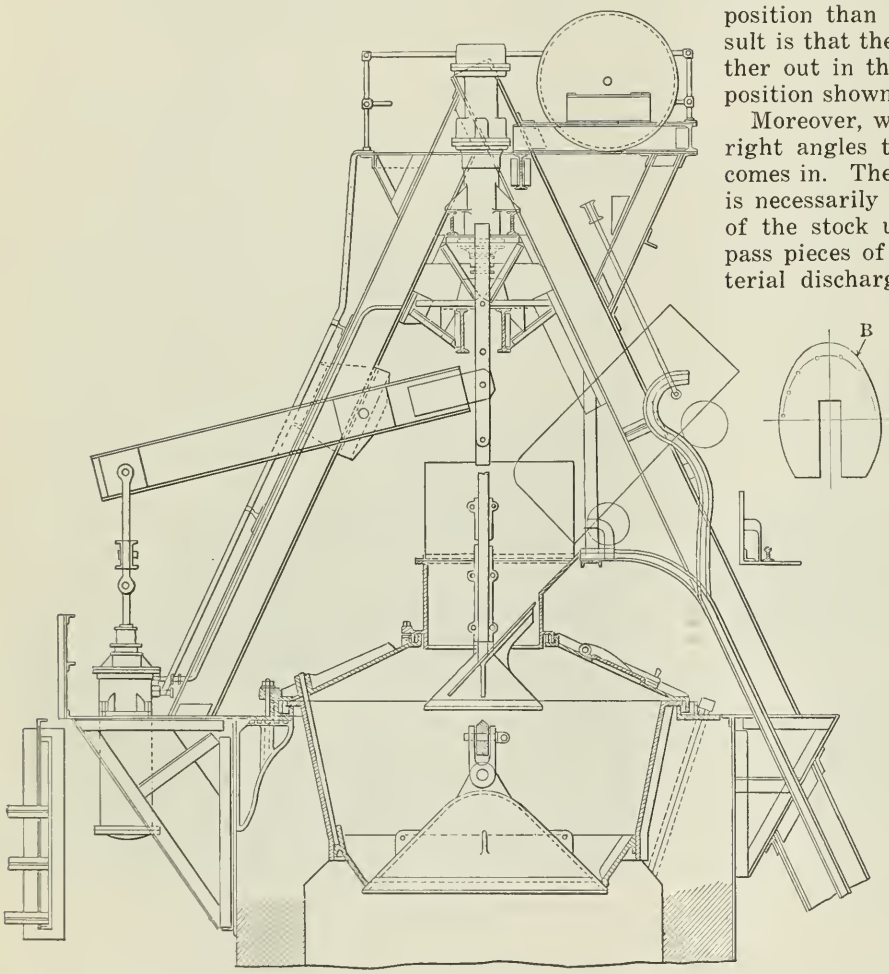


FIG. 18—BAKER ROTATING TOP

With the passage of time many of the features of the design which caused these difficulties have been overcome, and in the North where furnace tops commonly work at quite low temperatures, about 400 deg. or below, these mechanical troubles have not been so severe, but in Southern practice, with greater coke consumption, and much hotter top conditions, the Brown top has in more than one instance been discarded for the purely mechanical reason that it could not be kept in successful operation, the situation frequently being complicated by the fact that mechanics of sufficient skill to operate a mechanism of this kind successfully were, in past years, scarcer in the South than in the North.

In addition to these mechanical difficulties of operation the Brown top in spite of its appearance of perfect symmetry does not give an absolutely symmetrical distribution.

An examination of Fig. 4 will show that the line of the distributor in the position drawn is practically a continuation of the line of the bottom of the skip, so that the material discharging from the latter has only to continue on its way straight through the distributor, and is thereby delivered from it with velocity practically unchecked. But when the discharge spout of the distributor is in the position opposite to that shown, its slope is almost at right angles to the line of discharge from the skip, and material delivered upon it is therefore brought practically to a standstill, and starts again virtually from rest, so that its velocity of delivery from the distributor is very materially less from this position than from the position opposite. The result is that the material is thrown considerably further out in the hopper with the distributor in the position shown, than in its opposite position.

Moreover, when the spout of the distributor is at right angles to the position shown, another effect comes in. The spout is not a mathematical line, but is necessarily a broad opening to permit the escape of the stock under any and all conditions, and to pass pieces of scrap of considerable size. The material discharging into the hopper from the skip has a very considerable horizontal component to its velocity when it strikes the distributor, and instead of discharging down the axis of the spout, this horizontal velocity takes it over to the far side of the spout, whether the latter be turned toward or away from the observer.

The effect of this is, of course, to put more material on the side of the bell opposite to the skip than on the side next to it. In other words, in spite of the axial location of the center of the distributor the horizontal velocity of the stock imparted by the skip persists to some extent and carries the center of gravity of the pile of stock as it rests on the bell considerably beyond the axis of the furnace. That is the side of the furnace next the skip receives a considerably smaller portion of every charge than does the opposite side. Unsatisfactory furnace work has been traced directly to this cause in several cases.

The Baker Top

This may be considered as a modification of the Brown top in that it distributes the material in heaps on the main bell. It is shown by Fig. 18. Endeavor has been made in the design of this top to overcome the mechanical difficulties due to the great weight of the rotating parts, the large radius of the sliding surfaces in the Brown and the somewhat complicated mechanism required to drive it, and also to reduce to a minimum the height from which the coke is dropped so as to reduce coke breakage. The main bell, hopper, and lip ring are clearly shown by the drawing, and are of standard construction, but, as is necessary in most central types of stock distribution, the main bell is not supported on a single central rod; instead it is hung to a horizontal central equalizing beam from the two ends of which rods run up to the ends of the double main bell beam. A section of the equalizing beam, with its sharp-edged top

to divide the current of stock, and prevent any disturbing action on the descent of the latter, is plainly shown on the drawing. The main bell rod on the far side is shown broken away below the top of the upper hopper, but a short piece is shown attached to the end of the main bell beam.

In this design there is a gas seal bell practically identical with the upper bell of the ordinary non-rotating double bell charging apparatus, but in this case the bell has fastened to it a plate which is elliptical in outline and is set parallel to one side of the conical surface, and constitutes a sort of slanting piston working in the receiving hopper which is nearly cylindrical, diverging slightly at the top, as shown in the drawing. The upper bell is rigidly keyed to the lower end of its central bell rod. By means of its suspension rod the bell with its extension plate attached is rotated through a certain angle each time it is raised and lowered. When the upper bell is open, and in the position shown, the plate acts practically as a continuation of the lip of the receiving hopper and discharges the entire skip load on the opposite side of the furnace. The upper bell is then closed and opened again, which brings the deflecting plate into a position in the horizontal plane approximately to right angles of that shown. This delivers the next skip load onto the bell practically at right angles to the first one, the third is approximately opposite to the first, and the fourth practically completes the cycle, but if the "hunting tooth" effect used by Brown is desired, the cycle is not exactly completed.

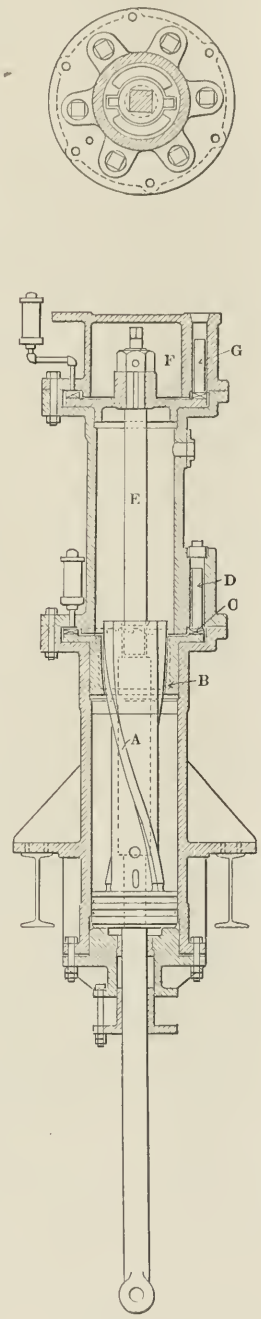
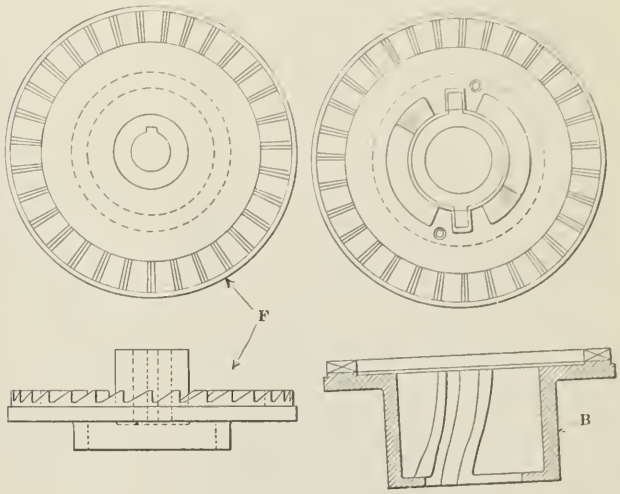


FIG. 19—ROTATING GEAR OF BAKER TOP

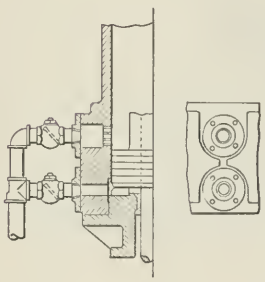
Instead of an arrangement of gears for rotation recourse is had to what is known as the rifle barrel cylinder. This device has been in use for many years for securing the rotation of rock drill bits. The cylinder which operates the upper bell is immediately over it, and inverted so that it operates directly without the intervention of levers or other devices. This makes an extremely simple design.

The operation of the rifle bar cylinder is shown by Fig. 19. The piston carries two helical vanes A which work in corresponding grooves or threads in the nut B which has ratchet teeth cut in its upper surface. These are engaged by vertical gravity pawls D in pockets spaced around the cylinder. They prevent the rotation in one direction of the nut B. A square opening at the top of the chamber on which the helical vanes are cast is an easy sliding fit on the square rod E, which carries on its top a circular plate F, to which it is rigidly keyed, and which has on its top surface ratchet teeth engaging with pawls G exactly the same as those of B and operating in the same direction.

On the down stroke of the piston, the action of the vanes forces either F to turn to the right or B to the left, but the ratchets G do not allow F to turn to right while the ratchets D do allow B to turn to the left, which it does. On the up stroke the pawls engage with the ratchet teeth C and prevent the backward rotation



of B which thus compels the rotation of the disk F in its turn.



Thus every cycle (up and down stroke) of the movement of the piston forces the bell and deflecting plate to rotate through a given angle. The amount of the rotation is determined by the pitch of the helical vanes, and the stroke of the cylinder. The latter is intended to be constant and, therefore, the angle of rotation of the upper bell with its deflecting plate is also constant.

The upper portion of this cylinder has no function except to enclose the apparatus and prevent the entrance of the grit and dirt which always abound on top of furnaces, and which have done so much to destroy charging mechanism. The cylinder is virtually a single-acting one, since the weight of all the parts acts downward and suffices for the down stroke, steam being used only for the up stroke and to cushion the down stroke.

This type of top has given good satisfaction at a number of plants, but its use has been abandoned at a number of others, since it was claimed that the benefit obtained from its form of distribution was not sufficient to offset the possibility of the small bell being stuck with its deflecting plate in one position, and dumping the stock to one point on the main bell for a number of charges, or even hours, if this condition was not discovered. For it is evident that if the small bell fails to operate between skip loads the position of the deflecting plate will be left unchanged, while there is nothing to prevent the indefinite continuance of dumping in this position. This, of course, would make the worst possible type of stock distribution, and would ruin the work of any furnace in a very few hours.

There is with this design the possibility of jamming

the deflecting plate against the wall of its slightly tapering receiving hopper by the entrance of lump material back of the plate, and while the probability seems slight, this chance, in addition to the discarding of the top by at least one large plant has proven sufficient to reduce its popularity. It is probable that the top has been successful at plants using lump ore, or a mixture of lump and fine, and less successful at plants using all fine ore, for reasons which will appear later. This is in accordance with the facts in regard to the continued use of these tops. Those within my knowledge at plants where the ore mixture is lumpy have given far greater satisfaction than those in the Lake Ore district.

The McKee Top

It has been very widely believed by many furnace men, and is even yet, that one of the essential characteristics of a revolving top is that if the revolving apparatus ceases to work it should still continue to give

FIG. 20—KENNEDY TOP

a reasonably good stock distribution. This means that dumping in heaps is barred because as explained in regard to the Brown and Baker tops, if they cease to rotate they give the worst conceivable distribution. This then implies that the stock must be dumped in annular layers as nearly uniform as possible, and that any irregularities in the layers due to the irregular discharge by the skips into the receiving hopper must be eliminated by revolving the latter.

This idea seemed to have occurred almost simultaneously to various engineers, but the credit for having first applied it successfully undoubtedly belongs to Arthur G. McKee of Cleveland.

The earliest form of this top consisted simply of a conical receiving hopper into which the skips dumped, terminating in a hopper of steeper slope below whose bottom was closed by an ordinary gas seal bell operated through a hollow bell rod which encircled the main bell rod. The hopper was mounted on ball bearings set well back from the line of the hopper, and carefully designed to keep the dust out from above, and give it ample opportunity to fall out below, holes being drilled at intervals in the bottom of the ball race to facilitate the latter purpose.

The gas seal bell, of course, requires to rotate with the hopper and therefore the hollow bell rod is provided with a small ball bearing near its upper end to permit the lower part and the small bell to rotate without interfering with the operating mechanism above.

Probably one of the most important features of the design practically is the extension of the ball track to a path well outside of the closest point on the hopper, which is carried by radial arms extending in from the upper ball race. This makes an air space between the ball race and the hopper so that unless the latter be heated to a red heat or above, the ball race still remains relatively unaffected and able to perform its functions.

This apparatus is not driven by the rotation of the sheaves through ratchet wheel and gears as in the Brown, but is provided with an independent motor operating through reduction gearing and controlled from the operating platform at the bottom of the furnace.

The general appearance of this early form of this top is shown by Fig. 20, which however is not a McKee top, but a top designed by Julian Kennedy of Pittsburg, on exactly the same principle as the McKee, but rotated by a wire rope passing around the hopper and down to the ground level, where it is moved by hydraulic cylinders or other suitable mechanism to give the desired rotation to the hopper. In principle the design is in all respects similar to the McKee.

In the McKee top contacts are attached to the hopper at four points and by means of wires carried down to the operator's platform these light indicator lamps when they come into certain positions.

In operating this first design a skip was dumped into the hopper which was then rotated through ninety degrees. The second skip was then dumped and the hopper again rotated, and so on to the fourth skip load which completed the cycle, the upper bell was then opened, permitting the charge to descend onto the main bell from which it was dumped after the upper bell was closed. The process was then repeated.

Almost innumerable modifications of this system were designed to eliminate certain irregularities which briefly are the same as those I have pointed out in connection with the dumping of barrows into the hopper in hand-filling. The location of the first skip load in the hopper and the room it occupies is very different from that of the second and third, and still more different from that of the fourth, which is likewise different from that of the second and third. Moreover with the double skip there was a serious irregularity which does not appear from the examination of a side elevation of one of these tops. From this it might appear that both skips dumped in the central plane between them, but as a matter of fact one dumps well on one side, and the other as far on the other side of this central plane, so that two successive loads are a considerable distance apart in the hopper irrespective of its rotation. It will be obvious on a little consideration that when this distance is combined with that arising from the constant angle of rotation, two adjacent skip loads may be the sum of these two distances apart, and the next two only their difference, with consequent great variation in the shape and location of the resulting heaps.

Many furnaces equipped with tops of this type while they apparently had a good stock distribution, gave extremely poor results, and as furnaces working under very different conditions showed similar results along a certain line which was not nearly so noticeable with any other type of top, it seemed reasonable to assume that the trouble was due to this type of distribution.

The furnaces filled in this way scoured out their linings in a zone twenty or thirty feet above the tuyeres, not on one side as so frequently happened with non-rotating skip-filled furnaces, but quite regularly all

around. The blast pressures were high, furnace control unsatisfactory, and fuel consumption apt to be excessive.

The real reason for these results has, so far as I know, never been worked out, but that they did exist, and that they were directly chargeable to the type of distribution used at least in one case has been demonstrated in my own experience so clearly that no unprejudiced observer could retain any possible doubt. I shall revert to this phase of the subject later.

It was in order to overcome these difficulties, whatever their reason may be, that Mr. McKee has in recent years redesigned his top so as to eliminate some of the worst irregularities. The new design is shown diagrammetically by Fig. 21.

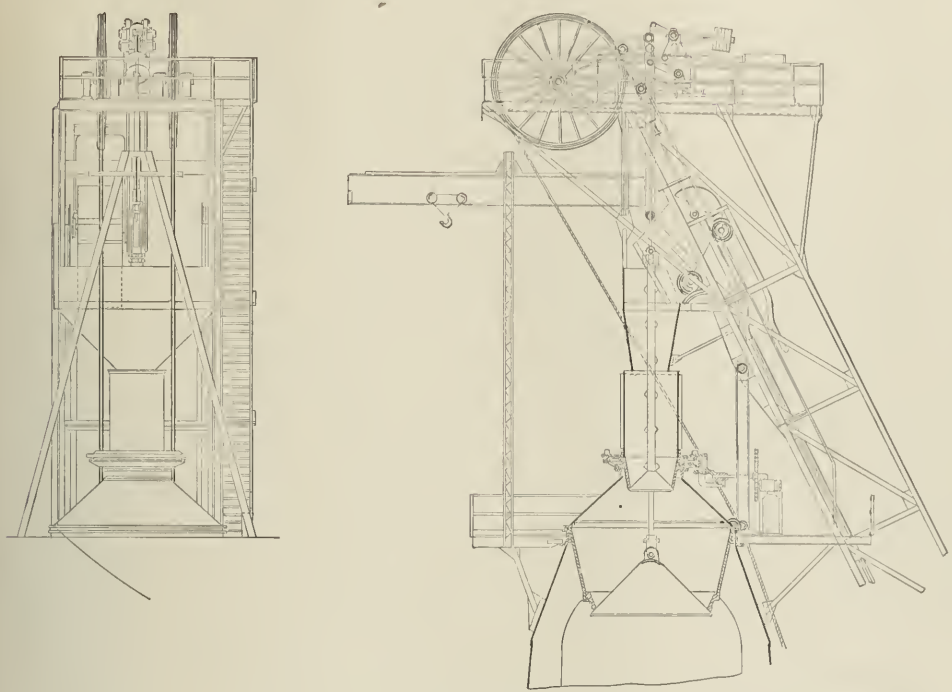


FIG. 21—RECENT DESIGN OF MC KEE TOP

The original rotating conical receiving hopper is entirely eliminated and is replaced by a flat triangular stationary receiving hopper through which each skip load in turn passes into the cylindrical rotating hopper below. This has the great advantage of practically centering the charge to begin with, and thereby eliminates some of the worst irregularities of the original design.

The revolving hopper is now being rotated preferably to six points instead of four, and so equalizes any irregularity which may occur in the discharge of the skip load into the hopper by throwing it to each one of the six successive radial positions in turn.

The design of ball races carried well away from the hopper proper, the provisions for preventing the entrance of dust and for allowing it free exit are maintained substantially as they were in the earlier design. It is no more than fair to say in this connection that mechanically this top in my experience gave a minimum of trouble, and I think that this experience has been quite general. I have not operated any furnaces with the improved design, but my information is that many of the troubles which prevailed with the older design have been diminished with this, and that the results are very much better, as is to be expected from the removal of the irregularities due to the varying distribution of the skip loads around the conical hopper.

(*To be concluded in April issue*)

The Hardening of Metals before the Faraday Society

The last meeting of the Faraday Society in London was devoted to an interesting symposium on the hardening of metals.

The president, Sir ROBERT HADFIELD, opened the discussion with an introductory address. Referring to the history of the most important "hardened" metal in the world, namely steel, he said that the world's future progress literally depended upon understanding correctly and in a scientific manner "the hardening of metals." The accurate determination of the hardness of steel alloys was now being investigated by a special research committee of the Institution of Mechanical Engineers. They were that night going to discuss the *rationale* rather than the practical applications of hardening. Having referred with deep regret to the great loss sustained by the science of metallurgy in the death of Dr. Martens, in whose honor Osmond had invented the metallographic term "martensite," he concluded by showing a specimen, probably the first to be exhibited in modern times, of an ancient piece of high-carbon steel which had been hardened by quenching. It was taken from beneath the stone pillar of Heliodorus at Besnagar, India, and it contained 99.2 per cent. Fe, 0.70 per cent. C, 0.04 per cent. Si, 0.008 per cent. S, 0.20 per cent. P, 0.02 per cent. Mn, and traces of nickel and chromium. This specimen, perhaps more than two thousand years old, was the first example of ancient steel which he knew of that contained sufficient carbon to be called steel.

Dr. G. T. BEILBY read a paper entitled "Some Recent Papers on Hardening and Overstrain in Metals, and the Bearing of These on the Author's Amorphous Theory of the Hardened State."

I. Hardening of a pure metal may be caused by cold working or by chilling.

II. Hardening of alloys, of mixtures of metals, or of mixtures of metals and metalloids may be caused by cold working, by chilling, or by the mere admixture of different kinds of molecules, either simple or compound.

In Class I, if the amorphous-crystalline theory of the hard and soft states is accepted no further explanation is needed, but in view of the fact that this explanation is not yet universally accepted, the facts and conclusions on which the theory is based are briefly discussed. The essential distinction between molecular aggregation in the two states is shown to consist in *mutual constraint in the one state and freedom of vibration in the other.* The vibrational freedom of the molecules in the crystalline state is an essential and characteristic feature of that state and inevitably leads to potential mechanical instability. Mutual constraint of the molecules in the amorphous state inevitably leads to greater mechanical stability. Mutual encroachment into each other's sphere of vibration enhances the mutual attrac-

tion of the encroaching molecules. This view falls in line with the ascertained facts as to the storage of energy in the hardened metal which is released on solution, the loss of elasticity evidenced by acoustical and other phenomena, and the electrical, magnetic and optical phenomena which probably indicate interference with the freedom of the electrons as well as with the vibrational freedom of the molecule as a whole. Further the mechanical instability of the crystalline state is shown by the ease with which the surface of even brittle, non-plastic, crystalline metals and other substances can be flowed into a smooth, hard, vitreous layer or skin. The steps in the recrystallization of the hardened metal as the temperature is raised to the point at which the whole mass is apportioned among fully developed crystalline grains supply further confirmation of the reality of the distinction between the two states.

Class II. The hardening of alloys and mixtures. If the amorphous-crystalline theory is accepted for Class I it must also be accepted for Class II, wherever the condition of flow at internal surfaces can be shown to exist either as a result of cold working or from contraction strains due to chilling. In this class the amorphous or thermally metastable state may also be produced by sudden solidification from the liquid state. Even when solidification is complete, during subsequent slow cooling molecular rearrangement among the different constitutents or phases may occur, and these changes may make either for greater or less hardness of the aggregate in whole or in part.

Mr. J. C. W. Humfrey, of Sheffield, read a paper on "The Part Played by the Amorphous Phase in the Hardening of Steel."

The conclusions arrived at in the paper may be summarized as follows:

The hard structure which can be produced in carbon steels by quenching and in certain alloy steels by normal cooling, is due to the presence of a hard amorphous solution of α iron and iron carbide, which solution may be compared to Beilby's amorphous phase formed by overstrain.

To explain the formation of this amorphous phase the author advances a theory that the passage of a substance from one allotropic modification to another of different crystalline form involves the temporary formation of an amorphous state, corresponding to the liquid phase of the modification about to be formed. In steels such a change occurs at Ar 3; and if, due to sudden cooling or to the presence of certain alloyed elements, the change-point is lowered to a temperature below that at which crystallization in the viscous mass becomes difficult, then the amorphous form will be retained in a metastable form in the cold.

The theory is supported by evidence derived from the micro-structure and physical properties of carbon steels hardened by quenching, and of alloy steels which attain a hard structure even when slowly cooled.

Professor C. A. Edwards, of Manchester, read a paper on "The Hardening of Metals by Quenching."

Steels not being the only metals which can be hardened by quenching, must be regarded merely as the higher members of a group of alloys which undergo similar changes, namely, undergo decomposition at certain critical temperatures, during which evolutions of heat occur. The critical heat changes are probably a result of the quick cooling, for if this be increased the temperature at which the changes occur is lowered and their thermal magnitude decreased; in other words, there is an increased tendency to prevent the inversion and keep the heat of the carbide change inside the cold material. Can the highest obtainable rates of cooling completely suppress the heat change? The experiments of Benedicks point in this direction and lead to the view that hardening is caused by the suppression of the heat of the carbide inversion. It has been objected that the structures of quenched steels do not support this view, but Carpenter and the author consider these to be a result of the internal stresses set up and not to indicate a difference in physico-chemical constitution. Thus the hardness produced by quenching is brought about by crystal twinning and possibly direct slipping, and the resulting formation of amorphous layers. The author meets Rosenhain's objection that the stresses set up cause no serious flow or movement in the quenched steel. He points out that Harniot has considerably increased the hardness of cylinders of silver by pressure alone without any apparent deformation. It is unnecessary to suppose with Humfrey that in passing from one allotropic form to another crystals pass through an amorphous stage; if so, where would the energy absorbed come from? On the other hand, if twinning takes place, energy would be absorbed and stored up in the amorphous layers. The facts brought forward by Dr. Desch are considered not to be opposed to the theory of hardening by twinning.

Dr. Cecil H. Desch, of Glasgow, presented a paper on "The Hardness of Solid Solutions," which was communicated by Dr. T. Martin Lowry.

Any complete theory of hardening must take into account the increased hardness which accompanies the formation of solid solutions (mixed crystals). The hardness of the elements is closely proportional to the internal pressure, a/v_2 in van der Waals' equation, and the hardness of solid solutions has been attributed to an increase in the internal pressure. Native copper has been shown by the X-ray method to have a simple cubic space lattice. Gold and silver are probably quite similar, and the atomic volumes of the two metals are almost identical. It is, therefore, difficult to see how any considerable distortion of the space lattice can occur when the two metals are alloyed. The density is unchanged by alloying, and the metals interpenetrate freely by diffusion, but the hardness is twice as great as that of the single metals. Transparent isomorphous mixture of salts may be obtained without optical evidence of internal strain, and yet exhibit increased hardness. A great difference in the attractive forces between the atoms is not easily conceived in the simple case of silver and gold. No theory at present accounts satisfactorily for the facts.

Dr. Cecil H. Desch also contributed a note on "Crystal Twinning and the Martensitic Structure."

The theory that the hardness of quenched steels and other alloys is due to repeated twinning is open to serious objections. It is shown that a twinned martensitic structure may be obtained in metals and alloys which are not hard. A very slowly cooled low-carbon steel, previously overheated, showed a characteristic martensitic structure in pearlite of the usual hardness. The hard constituents of quenched alloys may or may not exhibit twinning, and the latter is at most an accompaniment, not a cause, of the hardness.

Mr. Andrew McCance, of Glasgow, contributed a paper on "The Interstrain Theory of Hardening," which was read in abstract by the secretary.

Only two real allotropic forms of iron exist—gamma iron, which can dissolve carbon and is non-magnetic, and alpha iron, which does not appreciably dissolve carbon and is magnetic at ordinary temperatures. "Beta iron" is only alpha iron which has lost the property of ferromagnetism from purely thermal causes, and the pseudo-change-point at A2 is due to a variation in the specific heat which always accompanies this transition. Gamma iron cannot be made ferromagnetic by any treatment such as permanent deformation, etc. Metals

after deformation are best described as being in a condition of "interstrain," since there are facts which cannot be explained by the theory of a hard amorphous vitreous phase, such as the dissimilarity in magnetic properties of strained gamma and strained alpha iron and the hardening effect on metals of high fluid pressure without any resulting deformation. Hardening by deformation results from purely structural causes which affect the crystalline state.

In steels during cooling two transformations can take place: (*a*) the change in the iron from gamma to alpha, and (*b*) the change in the state of solution of the carbon. Quenching suppresses (*b*) but allows (*a*) to proceed, and the alpha iron formed under this condition is interstrained and hard. This accounts for the magnetic properties of quenched steels and for the fact that the hardness reaches a maximum independent of the carbon content. Austenite, which is soft, results when both transformations are suppressed, but when tempered at about 250° C., or immersed in liquid air, the transformation from gamma iron to alpha takes place suddenly and an increase in hardness corresponds with the formation of the interstrained alpha iron.

Professor HENRY M. HOWE, of Columbia University, contributed to the discussion a paper on "Hardening with and without Martensitization," which was communicated by the president.

Of the six methods of hardening according to the author's classification, five are martensitizing and one non-martensitizing. The former ways of hardening are (1) that of carbon steel by rapid cooling; (2) that of steels with an intermediate proportion of manganese or nickel by air or other moderately slow cooling; (3) that of Maurer's austenitic manganese steel by cautious reheating; (4) that of 25 per cent. nickel steel by liquid-air cooling; (5) cold deformation of any ductile metal. The non-martensitizing way of hardening is holding manganiferous ausentie (Hatfield's manganese steel) shortly below the transformation range (e. g. at 550°), whether the cooling thence be fast or slow. It is shown how all these methods of hardening but the last can be explained by the amorphous theory. This is described as referring the hardening to the presence of a very great proportion of iron made amorphous by the formation of innumerable slip bands, caused by the sudden expansion due to the starting of the $\gamma \rightarrow \alpha$ transformation at innumerable nuclei, and its arrest by the pressure thus caused. The martensitization which occurs in all these cases (formation of the very hard acicular constituent known as "martensite") tallies with the conception of innumerable slippings. The amorphous theory cannot explain the sixth method of hardening (if this also takes place in the absence of carbon—this is being tested), because at such high temperatures amorphous iron should be able to recrystallize. The γ theory, which ascribes hardness and brittleness to martensite because it is an undercooled solution of γ in α, is shown to be unsatisfactory in all of the six cases. If hardening No. 6 takes place in the absence of carbon, the author considers the β (an alleged intermediate allotropic modification of iron) more credible than the amorphous theory, in spite of the surprising slightness of the discontinuity in the cooling curves at the supposed β-α transformation point.

Dr. T. M. LOWRY and Mr. R. G. PARKER presented a "Note on Metallic Filings."

They suggested that these were probably cold-worked in an extreme degree. They regarded the remarkable properties of fresh filings of the silver-tin "dental alloy" as due to the presence of a large proportion of Beilby's amorphous phase. The change of density produced by "ageing" these filings at 100 deg. C. is larger than in the case of pure metals, but experiments now in progress have shown that other metallic filings exhibit analogous changes of density when annealed at 100 deg. or even at 80 deg. C. These temperatures are much below those given by Beilby for annealing temperature of hard-worked alloys, and are very much below the annealing temperatures commonly used in metallurgical work.

Dr. J. E. STEAD, in a communication made by the president, stated that in his opinion we had not sufficient data on which to found any definite conclusion as to why steel is hardened by heating to above Ac 1-2-3 followed by quenching, but it was certain that the carbon was mainly responsible. The different behaviour of hardened and annealed steel when treated with chemical reagents proved that there was a difference in their chemical constitution. The allotropic theory could only be regarded as a tentative hypothesis. The solid solution hypothesis too might be one of several pointing in the right direction. The internal stress hypothesis also might be more or less correct, but it must not be forgotten that 0.9 per cent. carbon steel could never be made intensely hard merely by stressing and distorting in the cold. Again, iron saturated with 1.7 per cent. phosphorus, the phosphorus in this case being in solid solution Fe_3P in iron, is difficult to drill, while Cleveland pig, or any grey iron containing even 2 per cent. or more phosphorus, in which case the Fe_3P is in a free state, can be readily machined.

Dr. Stead opposed the view that twinning was an indication of hardness, nor did he consider that martensite probably consisted of a mass of twin laminæ. The same steel containing 0.9 per cent. carbon, whether quenched from 750 deg. C. and barely martensitic or quenched from 900 deg. C. with a pronounced martensitic structure, is equally hard, in spite of the fact that the internal stresses in the second case must be much the greater.

In conclusion, although we had not sufficient data on which to base dogmatic conclusions, there could be little doubt that on the carbon condition mainly depended the extreme hardness of steel.

Mr. ANDREW MCCANCE in a written communication emphasized the difficulty of explaining the hardness produced without deformation by the action of high pressures on metals, and the magnetic properties of strained α and γ iron, by Dr. Beilby's theory of the amorphous phase. Again, had it been shown experimentally that the amorphous state was actually harder than the crystalline for any substance at the same temperature? Mr. McCance also dwelt on the difficulty of correlating magnetic properties with the amorphous phase theory, and he criticized the way in which Mr. Humfrey met the difficulty by assuming that in the crystalline space lattice it was the *molecules* which were regularly spaced. Mr. Humfrey's view that structureless martensite was formed when all the austenite had been transformed to amorphous α iron, while the more prominent structure obtained from a higher quenching temperature was due to the retention of much austenite, was not in accordance with experimental evidence.

The president, in opening the general discussion, was pleased to notice that Dr. Stead emphasized the fact that the main factor in the question of the hardness of iron alloys was the presence of carbon. It was also evident that Professor Howe, who had kindly sent a communication all the way from America, was also coming back to a carbonistic theory. Sir Robert Hadfield felt so strongly on this matter that he had offered a research prize of £200 in order to stimulate the study of the carbides of iron and of iron alloys generally.

Professor T. TURNER said that the subject under discussion was of extreme importance. Sometimes we required a metal to be soft, and sometimes its value de-

pended on its being hard; we therefore want to know the reason why it is hard or not hard. He agreed with Dr. Beilby that we should know more of the molecular structure of the metals. There were two kinds of hardness which should be kept distinct from each other in one's mind. One was the hardness caused by mechanical deformation, and the other was the hardness brought about by a chemical change which produced a closer packing of the molecules of the material. Still it must be borne in mind that when a metal is hardened its density increases to only a very small extent. Another thing which altered molecular distance and produced hardness was the formation of solid solutions. There must be enormous forces brought into play when one substance dissolves another, and it is natural to assume that closer packing of the molecules results. Professor Turner explained most of the changes in hardness which took place in various steels by the solution or the segregation of the various carbides at different temperatures.

Dr. W. H. Hatfield pointed out that at least three of the theories brought forward that evening were really an indirect result of Beilby's work on the amorphous theory. Dr. Hatfield had independently arrived at views similar to those of Mr. Humfrey. It seemed obvious that when γ iron changes to α iron it passed through the mobile or amorphous phase; but during quenching the amorphous phase was presumably side-tracked and remained unchanged, thus producing hardness. Dr. Hatfield pointed out objections to his and Mr. Humfrey's views.

Mr. T. G. Elliott was glad to observe a revival of interest in carbon as a factor in the cause of hardness, and expressed the view that an examination of steels under heat treatment would throw great light on the subject.

Dr. F. J. Brislee asked Dr. Beilby whether the passage from the amorphous to the crystalline stage would have a definite transition point, and whether, in the case of aluminium, this point was identical with the annealing point.

Mr. S. A. Main pointed out that the various theories advanced that evening were qualitative rather than quantitative. What was badly wanted was a definite scientific unit in which to express hardness, especially extreme hardness.

Sir T. K. Rose asked Professor Edwards about the production of twinning in tin by bending. "How long did he leave the tin before examination"? He asked this question because tin anneals itself at the ordinary temperature in 24 hours.

The president, in reply, agreed with Mr. Main's view that a definite scale of hardness, which was independent of any particular method of estimation, must be arrived at. He mentioned that when measured by the rebounding test quartz was the hardest material known. Many of the theories advanced that evening must be wrong, because they required that the projectile of a 15-in. gun, which weighed a ton and had a glass hard surface, was in a state of strain. This was improbable, as the projectile could cut through 15 in. of steel without being fractured.

DINNER OF AMERICAN ELECTROPLATERS' ASSOCIATION

American Electroplaters' Society

The New York and Newark branches of this flourishing society held their sixth annual banquet at the Broadway Central Hotel, New York City, on the evening of February 20. Two hundred were present. Mr. de Joannis, editor of *The Brass World*, presided as toastmaster. Prof. J. W. Richards, of Lehigh University, honorary member of the society, charged the electroplaters with being "The Daddies of Electrometallurgy," and proved his thesis by referring to the development of electrometallurgy from the electroplating art. Mr. A. K. Selden, of the Crocker-Wheeler Electric Company, described the characteristics of "The Modern Dynamo." Dr. Hiram Lukens, of the Harrison Laboratory, University of Pennsylvania, described briefly the electro-analytic methods which platers can use to determine the metal content of their solutions.

The society has 14 branches and over 600 members. Its members are chiefly foreman electroplaters, and the society has been of great educational value to them. Mr. Walter Fraime, of Dayton, Ohio, is secretary, and the next meeting will be at Dayton, in the plant of the National Cash Register Company the first week in June. Everybody interested in electroplating is invited to attend the meeting.

At the meeting of the Newark Branch, March 19 next, Prof. J. W. Richards will lecture on "The A. B. C. of Electroplating."

Annual Meeting of American Institute of Mining Engineers

The 110th meeting of the American Institute of Mining Engineers was held in New York City from Monday to Wednesday, February 15 to 17, 1915.

The business meeting was held in the morning of Tuesday, with President B. B. THAYER in the chair. The various reports were submitted and accepted. The results of the annual election of officers were announced as follows:

Mr. WILLIAM L. SAUNDERS, president of the Ingersoll-Rand Company of New York City, is the new president of the Institute. Mr. Charles F. Rand, president of the Spanish-American Iron Company, and Mr. Benjamin B. Thayer, president of the Anaconda Copper Company, are the past-presidents on the Board. Messrs. Sidney J. Jennings and Philip N. Moore were elected vice-presidents. It was announced that the proposed amendments to the constitution had been adopted by a majority of almost four to one.

The feature of the social functions was the annual dinner, held at the Hotel Astor on Tuesday evening. It was exceedingly well attended, some 300 members with their ladies being present. The feature of the after-dinner speeches was the brilliant address of the president, Mr. B. B. Thayer, who reviewed the past year's work in the Institute, announced that Professor James F. Kemp had been elected an honorary member of the Institute, and introduced the new president, Mr. W. L. Saunders, as toastmaster. Speeches were then made by Mr. Gans S. Dunn, Mr. Job Hedges, Dr. R. W. Raymond and Mr. John C. Montgomery.

W. L. SAUNDERS, PRESIDENT AMERICAN INSTITUTE OF MINING ENGINEERS

Professional sessions for the reading and discussion of technical papers were held in the forenoons and afternoons of the three days, often two sessions simultaneously in adjoining rooms of the Institute's headquarters. All were very well attended. In the following report chiefly those papers which are of metallurgical and chemical interest, are noted.

Safety and Sanitation

The first meeting, on Monday morning, was devoted to safety and sanitation. Mr. Arthur Williams, of the New York Edison Co., presided. The four papers presented were: "Safeguarding the Use of Mining Machinery," by Frank H. Kneeland; "Safety Methods and Organization of United States Coal & Coke Co.," by Howard N. Eavenson; "Housing and Sanitation at Mineville," by S. Le Fevre; "Enlarging the Worth of the Worker and the Perspective of the Employer," by J. Parke Channing.

Iron and Steel

At the iron and steel session, held in the afternoon of Monday under the auspices of the Iron and Steel Committee, Dr. Albert Sauveur, of Harvard University, presided.

High-Blast Heats in Mesaba Practice

A paper on "High Blast Heats in Mesaba Practice," by WALTHER MATHESIUS, of the Illinois Steel So., South Chicago, Ill., was presented, in the absence of the author, by Mr. W. A. Forbes. The use of high blast heats on furnaces melting Mesaba ores is still the exception, the average blast temperatures carried on Mesaba stacks seldom reaching 1100 deg. F., while a large number of Mesaba furnaces have been and are operated on very low blast temperatures, ranging between 800 deg. and 1000 deg. F.

"Actual practice in recent years has proved a different conclusion, having shown that a considerable coke saving is still obtainable when the heats are raised above the 1100° line . . . During the last year, the blast temperatures of two of the Bessemer furnaces at the South Chicago plant of the Illinois Steel Co. were raised above the 1100° line, and for many months temperatures from 1100 to 1300° F. were employed, with the result that the coke consumption was reduced to extraordinarily low figures without causing any operating difficulties . . . Since it has been shown, therefore, that with proper furnace conditions it is not only possible, but profitable in coke economy, to carry high heats on Mesaba furnaces, the next problem is to generate these heats in the most efficient way, and without losing through inefficient stove operation the advantage thus to be gained. In other words, the problem of adapting furnace lines, raw materials, and operation to the new practice having been proved capable of solution, efficient heat generation, through suitable stove construction and operation, is of paramount interest to-day."

The author then discussed the provision of new stove equipment. The erection of a fifth stove is thought by many blast-furnace managers the best means of increasing stove-capacity, for two obvious reasons: (1) because it can often be done with practically no other changes to existing equipment, and (2) because it insures a greater regularity of blast temperature.

But a fifth stove means not only greater complications of operation, but a loss in efficiency due to the increase of radiating surface. The benefit of the regular maintenance of higher heats is obtained at the expense of stove efficiency, because the chief evil has not been removed, namely, the accumulation of flue dust in the stove checkers, which constitutes the greatest impediment to efficiency in stove practice. The only way to eliminate this definitely is to prevent the flue dust from entering the stoves, *i.e.*, to wash the gas thoroughly. In Mesaba practice the washing of the gas is especially important.

"It is the use of washed gas which has made possible the construction of stove linings with a view to stability and heat economy only, and without regard to the consideration of stove cleaning, which, if the gas be dirty, must become the prime factor in determining the checker-work construction. The checker openings, which, where unwashed gas is used, are usually 9 in. square, can, with washed gas, readily be reduced to as small a size as the draft will allow. The checker walls, which, with unwashed gas, are not considered

safe when less than 3 in. in thickness, can now be reduced to the limit set by the size of checker openings as determined by the proper relation of total brick volume to surface, and by the ability of the brick manufacturer to produce a strong, substantial firebrick. In this way, the heating surface of the checker work is increased, for instance, more than 50 per cent. by reducing the checker openings from 9 to 4 in., and the thickness of the checker walls from 3 to 2.5 in. At the same time, this construction eliminates the dead portion of the brick work, in the center of the thicker checker walls, which does not participate in the heat exchange, as is proved by the fact that during the ordinary heating and blowing periods it undergoes hardly any change of temperature.

"By using washed gas and changing the stove linings along the lines indicated above, any furnace plant can increase the heating capacity of its stove equipment without adding to the radiating surface. In many cases an increase which will fully meet all heat requirements can thus be obtained.

"With higher stove temperatures, better insulation of the stove shell gains importance. It can be obtained by making the outer brick walls thicker, and using for them two kinds of brick: a porous kind of highly insulating quality, next to the shell; and, inside of this, a course of common firebrick (except in the combustion chamber, where a lining of highly refractory brick is required). Under no circumstances should the depth of the insulating wall be sacrificed to the desire of increasing the heating surface. To get an idea of the heat saving which can be expected from a better insulation, one has only to consider that in most stove plants the radiation losses amount to fully 20 per cent. of the total heat generated.

"If sufficient heating capacity cannot be obtained within shells of a given size, the only remedy is to enlarge them, by increasing either the height or the diameter. In building new stoves a larger diameter should be chosen; and on existing units an increase in height is generally feasible and sufficient.

"With proper equipment and clean gas, stove operation becomes an entirely different problem. It is no longer largely a question of crowding as much gas and air into the stove as possible. The scientific rules of combustion can now be applied, and the stoves can be heated with a minimum amount of gas by complete combustion, proper draft regulation, and an even distribution of the combustion gases and air over the entire heating surface."

The author then discusses the combustion of washed gas and the distribution of the gases and gives in the final part of his paper a very interesting thermal analysis of the performance of No. 4 Blast Furnace at the South Works of the Illinois Steel Co. during the month of June, 1914.

The weight of materials passed through the furnace was burden 31,645 tons, limestone 6154 tons, coke 13,006 tons, product (including scrap) 17,319 tons, slag 7,811 tons, flue dust 691 tons, blast (excluding moisture) 51,592 tons, moisture in blast 539 tons, top gas (excluding moisture) 72,360 tons, moisture in gas 4,665 tons.

The final heat balance sheet is given in Table I.

TABLE I.—HEAT BALANCE SHEET FOR ONE TON OF PRODUCT

Generated

By	B.t.u.	Per Cent
Combustion C to CO	3,995,000	31.1
Combustion C to CO_2	6,754,000	52.6
Hot blast (heat content)	2,057,000	16.0
Moisture of the air in hot blast (heat content)	42,000	0.3
Total	12,848,000	100.0

Consumed

By		B.t.u.	Per Cent
Reduction of Fe_2O_3	6,133,300		
Reduction of Fe_3O_4	490,000		
	6,623,300		
Reduction of MnO	48,400		
Reduction of P_2O_5	17,000		
Reduction of SiO_2	418,500		
		7,107,200	55.3
Calcination of carbonates		702,000	5.5
Dissociation of moisture in blast		397,000	3.1
Carried off with the iron		1,142,500	8.9
Carried off with the slag		909,000	7.1
Carried off with the dry top gases		752,400	5.9
Carried off with the moisture in top gas		700,100	5.4
Radiation, cooling water, and unaccounted for		1,137,800	8.8
Total		12,848,000	100.0

The paper was discussed by Mr. J. E. Johnson, Jr., Dr. J. W. Richards, and Mr. W. A. Forbes and considered to be a highly valuable contribution to the metallurgy of iron.

Finishing Temperature of Rails

A paper by W. R. SHIMER, on the "Effect of Finishing Temperatures of Rails on Their Physical Properties and Microstructure" gave a summary of the results of experiments conducted by the Bethlehem Steel Co. during the past year.

The rails were rolled from reheated blooms. All the rail blooms were charged hot in a reheating furnace and brought up to about the original ingot-rolling temperature before rolling into rails. These rails gave better results in deflection, withstood a greater number of drops before breaking, and showed greater ductility than rails of identically the same composition and section which were rolled direct from the ingot.

The results of the very numerous tests are given in tables and the paper is profusely illustrated with microphotographs. While the results as to the advantages of reheating blooms on the properties of the rails seem conclusive, there are no conclusive results as to the best finishing temperature.

"There was a variation of 500 deg. F. in the finishing temperatures and a variation of 1.34 in. in shrinkage. Even with this wide range in temperature and shrinkage, it was impossible to determine, from the results of the respective tests, at what temperature a rail should be finished in order to obtain the best results, since all the tensile and drop-test results recorded are good, and practically identical. The results show it is equally impossible to decide what microstructure and shrinkage are desirable.

"Further, from the results of this investigation we have learned that rails rolled from reheated blooms are more ductile than those rolled direct from the ingot, regardless of their finishing temperature. Also, we have learned to be cautious with regard to judging from the microstructure as to the temperature at which a rail was finished and to be careful in drawing conclusions from the microstructure, alone, in rail-failure investigations. The microstructure appears to be controlled more by the rate of cooling from above the critical point than it does by the temperature at which it was finished. In regular practice rails cool uniformly, since hot rails are going to the bed continually, and therefore the microstructures do not vary as much as they have in this experiment."

Mr. W. R. Shimer's paper was discussed by Mr. Wm. R. Webster, Prof. Henry M. Howe and Dr. J. K. Burgess.

Sound Steel Ingots and Rails

A paper by Dr. GEORGE K. BURGESS, of the Bureau of Standards, Washington, D. C., and Sir ROBERT A. HADFIELD, of London, England, reported tests of rails rolled in one mill according to American practice, from eight ingots manufactured by the Hadfield special-feeding process (this journal, Vol. 11, p. 79, 1913), and a comparison ingot, supposed to represent the usual type of ingot from which rails are made in this country. The results are given in tables and diagrams in considerable detail.

"The examination of the split ingots shows the great superiority of casting large end up and feeding by the Hadfield special process, such an ingot being physically sound and uniform throughout and practicaly free from chemical segregation.

"The examination of the rails shows that for ingots cast by the Hadfield process, those cast large end up will give rails of uniform quality free from flaws of all kinds; those cast small end up may show a soft region in the web of the *A* rail but are otherwise sound. Those cast in the ordinary manner from piping or otherwise unsound steel may or may not give sound rails, depending upon the condition of the steel.

"In addition to the certainty of producing all sound rails by the special-feeding process from ingots cast large end up, there is a great saving in metal and a consequent increase in percentage of sound ingot available for rails—in these experiments an average of 90 per cent. for ingots Nos. 2, 3, 4, as compared with about 50 per cent. for the piping ingot and an uncertain amount from the rising type.

"The usual physical and chemical tests do not appear to give an adequate measure of the quality of rails. For example, the results of the tensile and drop tests and chemical analyses would not separate the sound from all the unsound rails here examined.

"The question may be asked, Is it not worth while to use, in the manufacture of rails, only sound steel which is cast and rolled in such a manner as to make practically every rail a sound and safe one? We believe this can be done without excessive cost."

The paper was discussed by Dr. Sauveur, Dr. Howe, and Mr. Hibbard. Dr. Sauveur spoke in high praise of the work of the Bureau of Standards and emphasized that if there is a method to make sound ingots, the ethical standpoint should not tolerate the use of unsound ingots for rolling rails. On the other hand in a discussion by Mr. F. W. Wood, it was stated that not all defects were eliminated by the Hadfield method, such as surface flaws and slag inclusions, so that it was still an open question how far rail failures could be avoided by the Hadfield process.

Other papers presented at this session were:

"Modern Gas-Power Blower Stations." By ARTHUR WEST, of the Bethlehem Steel Co. It was profusely illustrated by lantern slides and the possibility of an accurate measurement of the air (far superior to the use of Pitot tubes, etc.) was emphasized.

"Are the Deformation Lines in Manganese Steel Twins or Slip Bands?" By HENRY M. HOWE and ARTHUR G. LEVY. The evidence produced by the authors shows these lines to be slip bands, not twins.

"Structure and Hysteresis Loss in Medium-Carbon Steel." By F. C. LANGENBERG and R. G. WEBBER. In magnetic testing careful attention should be given to the previous history of heat treatment and the resulting internal structure of the metal undergoing test. A mere statement of its conditions as hardened or unhardened, annealed or tempered, is idle and often misleading. It would seem that a minimum hysteresis loss could be obtained by the combination of large grains with coarsely laminated pearlite.

"The Magari Iron-Ore Deposits, Cuba." By JAMES F. KEMP (illustrated by most interesting moving pictures).

American Potash

Simultaneously with the iron and steel session a session devoted to non-metallic minerals was held in an adjoining room. The question of possible American sources of potash was brought up in two papers.

Mr. CHARLES H. MACDOWELL, of Chicago, Ill., in his paper on "German and Other Sources of Potash Supply" referred to the inauguration of the manufacture of commercial fertilizers by Armour & Co. in 1894, his recommendations, and sketched the geology and mining of potash salts in Germany and elsewhere. As to the American possibilities he spoke as follows:

Some potash can be made as a by-product from other manufacturing industries. Practically no progress has been made in this direction in this country.

The sugar-beet tonnage in the United States totals 5,147,000 tons. Sugar-beet wastes from this tonnage could produce 30,900 tons of potassium carbonate, equal to 15,440 tons of pure potash.

Raw wool contains up to 20 per cent. potash salts. The wool clip of the United States weighs 298,000,000 lb. In wool scouring 7,450 tons of potassium carbonate or 4,470 tons of pure potash is washed out and lost. This could be largely recovered. Much raw wool from Australia and other countries is imported, and the potash from the handling of this wool could also be saved.

Potash from Cement Burning.—Many cements before clinkering contain small percentages of potash, say 0.1 to 0.25 per cent. In burning this is volatilized. While the percentage is small, the tonnage is so large it figures quite a production on paper.

Many experiments have been made to recover this volatilized potash. It has been worked out to a point where the physical part of the operation is a success. It consists of condensing the volatilized potash in chambers and dust collectors similar to the bag house used in smelters. Up to the present time, however, no cement manufacturer has produced potash as a by-product. Possibly the investment expense attached to its recovery figures against it. I have no data on this.

The industry is a possible source of a considerable tonnage of potash and in case of necessity can be utilized without any extensive changes in present methods of manufacture. Possibly cheaper recovery methods may be found.

At one time considerable carbonate of potash was derived from the ash from burning cotton hulls. These are now used for fodder, so no potash could be obtained from that source.

A few years ago tobacco stems were distilled destructively for nicotine and other products. The ash from this material contained high percentages of carbonate of potash. This method of handling has now been discontinued, but the potash in the ground tobacco stems is saved and used for fertilizing purposes.

This about exhausts the by-product possibilities as far as I know.

Hard-wood ashes and other ashes are gathered and used in fertilizing for their potash contents. City garbage contains appreciable percentages of potash. This garbage in many cities is recovered and used for fertilizing purposes.

The author then sketched the well known work of Government Bureaus, especially the Geological Survey, the Department of Agriculture, and the Bureau of Mines, and finally summed up as follows:

In by-product lines, the sugar manufacturer and the wool scourer might spend some money on solving their problem. The cement manufacturer could well afford to investigate potash manufacture from potash-bearing rocks in connection with cement manufacture.

If potash is to be produced in this country in quantity, some one must spend some money. There has been a noticeable reluctance on the part of American capitalists to finance serious research work, or prospecting by deep core drilling. To begin with, our mining laws and mineral withdrawal possibilities are discouraging. A German potash mine controls several thousand acres of mineral rights. The necessary capital investment would not be justified if this control was not legally obtainable. Potash mines with the necessary concentrating plants are expensive and a large acreage control is necessary. Deep core drilling or other development work on government lands by private individuals would not be justified during the present stage of development of the art of conservation as practiced by our legislators. A positive control of acreage must go with such preliminary work.

There is a large market for potash and the demand is growing. Possibly the lever of necessity may develop sufficient power to overcome the prevailing inertia. Up to now Searles Lake is the only nearby producer on the map.

Dr. WILLIAM B. PHILLIPS, Director of the Bureau of Economic Geology and Technology of the University of Texas, in a paper on an "Investigation of Sources of Potash in Texas" comes to the conclusion that the only hopeful outlook for the existence of workable beds of potash salts in Texas is in the direction indicated by Dr. J. A. Udden* in connection with the deep well at Spur, Dickens County, and in the almost wholly unknown region southeast of and bordering on New Mexico. Explorations in either of these areas would have to be in depth, with systematic chemical examination of cuttings and return waters.

White-Burning Clays

A paper by Dr. JOEL H. WATKINS, of Washington, D. C., on "White-Burning Clays of the Southern Appalachian States" dealt chiefly with the North Carolina, Virginia, and Georgia kaolins or china clays (residual); the South Carolina and Georgia kaolins or paper clays (sedimentary), and the Florida and Tennessee plastic kaolins or ball clays (sedimentary).

The economic aspects were sketched as follows:

In 1913 the United States produced white-burned products which had a total value of $31,443,450, and in the same year imported white-burned ware valued at $9,340,890. The total export of white ware from the United States in 1913 was valued at $149,281; thus showing that the total

*The Deep Well Boring at Spur, *Bulletin* of the Bureau of Economic Geology, University of Texas, No. 363.

value of the white-burned pottery products entered for consumption in the United States in 1913 was $40,635,059.

In 1913, the imports of kaolin or china clay into the United States amounted to 268,666 short tons, valued at $1,623,993, with an average value of $6.04 per ton. According to Parsons, "This kaolin displaced a like amount of domestic raw material which, if properly handled, has no superior." Against this, in the same year, only 197,276 short tons of kaolin and ball clay were produced in this country, which had a total value of $893,259 and an average value of $4.53 per ton. Thus it may be seen that our domestic production of white-burning clays is only equal to about two-thirds of our imports in quantity, and half of our imports in value.

In consideration of the wonderful reserves of high-grade clays in the territory described above, it would seem that the United States, instead of importing annually large amounts of clay, should produce enough to supply her own demands, and even be a competitor in foreign markets. There are several good reasons, however, for this great difference between imports and domestic production, but only reasons which are due to existing conditions, all of which can be easily overcome.

One of the principal objections made by American potters to domestic pottery clays is that the product is not uniform in character, or in other words, has not been properly prepared and classified before shipping. The potter justly demands a uniform product under guarantee, since the slightest variation in his ceramic mixture may cause the entire plant to be shut down until the irregularity is discovered and eliminated. Such variations may be of either chemical or physical character and may result in a lack of sufficient plasticity, a change in color on burning, a change in temperature at point of vitrification, a change in shrinkage, a tendency to warp and crack, and a failure to take the glaze.

To meet the requirements of the potter, therefore, the U. S. Bureau of Mines has wisely advocated a central depot where the output of a number of mines may be properly mixed and graded under the supervision of a trained ceramic chemist. Such a plant, if successfully engineered, should practically eliminate the present practice of mining to-day and shipping to-morrow, and should greatly stimulate the mining of kaolin by smaller operators. The output should demand a higher price than the clay is now bringing, and should capture the trade of our domestic potteries.

Such a plant, or holding company, could be operated successfully not only in the North Carolina residual kaolin district, but also in the South Carolina and Georgia sedimentary kaolin districts.

Another reason why American white clays are not more extensively used is because the clay mines, for the most part, are so remote from the manufacturing centers. Practically none of the white clays now being mined in the Southern Appalachian States are consumed in these States, and the bulk of the product has to be shipped by rail, more than 400 miles in the case of the North Carolina kaolins, more than 600 miles in the case of South Carolina and Georgia kaolins, and more than 700 miles in the case of Florida ball clays. If these clays were properly prepared, and could be sold under guarantee to the pottery plants, there is no doubt that the potter would get closer to the source of his raw materials.

Estimates submitted by a number of clay miners in the North Carolina field show that this material, under favorable conditions, can be produced at a cost ranging from $2 to $4 per ton, and has a selling price of from $8 to $9 per ton at the mines. In the South Carolina and Georgia field estimates were submitted showing a range in cost of production of from $1.50 to $3 per ton with a selling price of from $4 to $6 per ton. The writer was not able to obtain figures on the cost of production of Florida ball clay, but, considering the great thickness of the clay-bearing beds and the economical methods of mining, it would be reasonable to assume that the margins of profit should compare favorably with those of the North Carolina and Georgia mines.

In view of the large amount of white clay consumed by American manufacturers, and the growing demand for domestic clays, it would seem that the clay-mining business in this country is almost in its infancy. Also, a review of the distribution of the clay resources in the United States would point to the fact that America must in the future look to the South for her supply of domestic white-burning clays.

Mining and Milling

The morning session of Tuesday was devoted to mining and milling with the following program:

"Experiments on the Flow of Sand and Water Through Spigots." By R. H. Richards and Boyd Dudley, Jr.

"Development of the Butchart Riffle System at Morenci." By David Cole.

"The Boulder Batholith of Montana." By Paul Billingsley.

"The Main Mineral Zone of the Santa Eulalia District, Chihuahua." By Basil Prescott.

"Cloncurry Copper District, Queensland." By W. H. Corbould.

"Mining and Reduction of Quicksilver Ore at Oceanic Mine, Cambria, Cal." By C. A. Heberlein.

"Metallurgical Practice in Porcupine District." By Noel Cunningham.

"An Improved Form of Cam for Stamp Mills." By Arthur B. Foote.

"Method for the Determination of Gold and Silver in Cyanide Solutions." By L. W. Bahney.

Fuels

A technical session on fuels, under the auspices of the committee on petroleum and gas and the committee on coal and coke, was held in the afternoon of Tuesday. Captain Lucas presided.

The feature of the session—and a rather sensational feature—came at the end of the session in form of a paper, not on the printed program, by Dr. Snelling, of Pittsburgh, Pa., on "Synthetic Fuel Oil."

Gasoline from Synthetic Fuel Oil

Dr. Walter O. Snelling in his paper on "Synthetic Fuel Oil" sketched the results of an extended research carried out by him in following up a discovery which he made some five years ago. The gist of the very interesting paper is given in the following abstract:

When any hydrocarbon, such as kerosene oil, melted paraffin, vaseline, fuel oil, or any such material, is subjected to the treatment described it comes out after treatment a fluid having the characteristics of crude oil. Even water-white kerosene, after five minutes' treatment, comes out a dark green liquid by reflected light (dark red-brown by transmitted light), and which resembles ordinary Pennsylvania crude oil so perfectly that even an oil expert cannot pick out bottles of the manufactured crude when placed among bottles of natural crude.

This strong resemblance in appearance also extends to marked similarity in composition. When this "synthetic" crude is distilled, it yields gasoline, kerosene, gas oil, and lubricating oils, much as any ordinary crude oil would do.

By this process "synthetic" crude oils have now been made from such dissimilar materials as paraffin wax, kerosene, fuel oil, rod wax, bottom settlings, gas oil and many like substances. In every case the resulting "synthetic" crude oil has resembled natural crude oil and on distillation has been found to yield practically the same products.

Apparently this process discloses certain fundamental principles governing the transformation of hydrocarbon bodies such as has produced crude oil in nature. Apparently it also points out and discloses in a most interesting way the lines of work which must be followed to transform any hydrocarbon into any other hydrocarbon.

Much work has been done by others recently, in attempts to make gasoline from heavier oils. In general, all these processes have yielded light products in some ways suitable for use as gasoline, but having the disadvantage of a marked yellow color, and a bad odor, which could only be removed by treatment with acid, resulting in the loss of a large amount of material.

By the present process, we change any hydrocarbon into crude oil, and this crude oil gives about 15 per cent of absolutely colorless gasoline, without objectionable odor. The residue, after removing the gasoline, can be again put through the same process, when it will give more crude oil, and from this an additional 15 per cent of gasoline can be obtained.

This process can be repeated over and over, and in our experiments up to now we have obtained even from still residue (the very heavy residue remaining after petroleum refining) up to 55 per cent of colorless gasoline of excellent quality. From gas oil we have obtained 60 per cent of high grade gasoline, and from paraffin, 65 per cent of gasoline.

It should be emphasized that in every case the gasoline so produced has not been inferior, yellow, or bad smelling gasoline, but has been gasoline of the very highest grade, free from heavy ends (that is to say, free from products not of the proper gravity) and having an odor not one particle more objectionable than that of ordinary, carefully refined gasoline made in the usual way.

Apparatus and Process.—The present invention rests upon the discovery of the fact that, when any hydrocarbon is placed in a vessel of such size that the hydrocarbon occupies about three elevenths of the total volume, and is under these conditions heated to such temperature as brings about within the vessel a vapor pressure of 800 pounds per square inch, the hydrocarbon introduced into the vessel becomes changed into "synthetic" crude oil. For the best results a very small amount of a suitable catalyst (ordinary graphite, finely powdered nickel, copper, etc.) is added to the oil before the treatment described.

From the experiments made (representing some 2,000 tests) it appears evident that some very fundamental change is brought about in oil when treated in the manner described, and that this change is of so deep-seated an origin as to lead to the general rearrangement and regrouping of the molecules, and leading to the production of new chemical bodies very similar, if not absolutely identical, with the material present in natural crude oil.

It is not yet at all certain that this method is capable of practical application in oil refining, in view of the fact that the pressure employed is quite high for commercial work. On the other hand, the remarkable results obtained are of such nature as to lead without doubt to efforts being made to build apparatus of large size for such work, but the success of these experiments cannot now be foretold.

This research work has been conducted under the financial direction and assistance of Mr. John T. Milliken, of St. Louis, Mo., president of the Milliken Refining Co.

Non-Ferrous Metallurgy

An exceedingly interesting session, from beginning to end, was held on Wednesday morning, under the auspices of the Committee on Precious and Base Metals. Mr. CHARLES W. GOODALE presided during the first half of the session, Mr. E. P. MATHEWSON during the second half.

The first paper was presented by J. B. TYRRELL, of Toronto, Ontario, on "Gold-Bearing Gravels of Beauce County, Quebec," and illustrated by numerous lantern slides.

Chloridizing, Roasting and the Separation of Copper from Nickel

A paper by BOYD DUDLEY, Jr., of Pennsylvania State College, followed on "a study of the chloridizing roast and its application to the separation of copper from nickel." The investigation had been carried out at the suggestion of Professor H. O. Hofman at the Massachusetts Institute of Technology.

The purpose of the work was, first, to study some of the reactions that have been considered as a part of the mechanism of the chloridizing roast, and second, to study the conditions under which nickel oxide and copper oxide may be chloridized. While the production of chlorine gas by various reactions during the chloridizing roast may not be primarily useful in the chloridation of metal oxides and compounds, it nevertheless serves a useful purpose in preventing the dissociation and decomposition of chlorides once they have been formed; for example, the dissociation of cupric chloride into cuprous chloride and chlorine. Therefore it was thought that a study of some chlorine-producing reactions would prove of interest, and the first series of experiments dealt with this phase of the subject. The object of the latter part of the work was to show the possibility of treating heavy sulphide ores, such as those of Sudbury, Ontario, containing much iron and small amounts of copper and nickel, by chloridizing and removing the copper, leaving an iron-nickel oxide product suitable for smelting in the blast furnace for nickel-bearing pig iron. The chloridizing of the copper would, of course, be preceded by a roast for the removal of sulphur, the sulphur oxides being available for the manufacture of sulphuric acid, if under the local conditions this product would be of commercial value.

The author's laboratory experiments, while not permitting a conclusion as to the working of such a process on a large scale, prove the possibility of treating roasted pyritic ores, containing copper and nickel, by chloridizing the copper and leaching it from the iron and nickel oxides, leaving a product suitable to be smelted to nickel-bearing pig iron. The experiments also indicate the temperatures at which the roast should be conducted in order to secure the desired results.

Desilverization of Lead

A paper by F. C. NEWTON, of Maurer, N. J., followed on the "effect of Zn_3Ag_2 upon the desilverization of lead."

Refiners of lead by the Parkes process have always been solicitous of recovering the zinc used in the desilverization, and justly so, as the loss in zinc constitutes one of the heavy costs in this method of refining. Part of this loss is due to the absorption of zinc by lead, and in the present state of knowledge is not recoverable as metallic zinc. The remainder of the zinc, which finds its way into the precious-metal-bearing crust, is recoverable and naturally engages the operators' most exacting attention.

Careful elimination of the impurities in base bullion has enabled the refiner to produce a zinc crust better adapted to retorting, which reflects favorably in the zinc recovery; and to produce a richer crust, thereby lowering the zincking cost, as the increased efficiency of the zinc results in less of it being in circulation.

It is obvious that if the ratio of concentration be increased, a lessening of the amount of crust formed will ensue, throwing less work on the retorts and diminishing the amount of retort metal sent to the cupels, thus making an actual money saving in all these operations.

In the effort to obtain a rich crust, the metallurgist has increased the heat to a considerable degree, upon the assumption that at the higher temperature the zinc-silver alloy could be squeezed free from the adhering lead.

A further possibility for improvement suggested itself in the freezing-point curve of Prof. H. C. Carpenter, upon zinc and silver. Study of this curve disclosed the existence of a definite chemical compound, Zn_3Ag_2, with a freezing point of 665 deg. C., a promising compound for practical application.

In the experiment undertaken it was endeavored to force this compound into the crust, hoping thereby to obtain a higher concentration than formerly. It was recognized that in bringing a large kettle of lead to such a heat, more fuel would be used, the life of the kettle would perhaps be shorter, and other disadvantages would be experienced. As a commercial operation, the project would have to stand on its own feet, so the records were carefully kept to balance the advantages against the disadvantages.

The first experiment, however, showed such refinement unnecessary, as it was conclusively indicated that the melting point of the zinc-silver compound was so modified as to nullify its feasibility as a commercial factor. . . .

In every instance, the crust removed at the highest temperature, that is, just below the freezing point of Zn_3Ag_2, furnished the lowest retort metal. . . .

The tests clearly demonstrated the impracticability of removing the crust at a very high temperature. Further experiments were made to determine what beneficial result, if any, would be obtained by the greater heat. . . . In all cases where the greater heat was used for stirring and pressing, the dross and blue powder formed, especially the former, were far in excess of current practice. . . .

The conclusion to be drawn is, that as a commercial project, the slight increase in doré contents of the crust, which might be obtained from zincking at the greater heat, is more than counterbalanced by the attendant disadvantages. The current practice of to-day, dictated more or less by the question of fuel economy and better life of kettles, has been justified as a practical and efficient procedure from the standpoint of concentration. For comfort of operation, effect upon the men, etc., all arguments are in favor of zincking at a lower temperature.

The paper elicited quite some discussion in which Prof. H. O. Hofman, Prof. J. W. Richards and Mr. W. McA. Johnson participated.

A long descriptive paper by MANUEL EISSLER, of Paris, France, on "Copper Smelting in Japan," was then presented in abstract by Mr. Burr A. Robinson and briefly discussed by Dr. J. W. Richards.

Coal-Dust Fired Reverberatory Furnaces at Copper Cliff and Anaconda

Two very interesting papers on coal-dust fired reverberatory furnaces were then presented. Mr. David H.

Browne, of the International Nickel Company, spoke in his characteristic humorous and modest style on Copper Cliff practice. The paper by Mr. Louis V. Bender, of the Anaconda Copper Company, dealt with the practice at the Washoe Reduction Works.

Mr. David H. Browne, in his paper on "Coal-Dust Fired Reverberatory Furnaces of the Canadian Copper Company," gave first a historical sketch and noted the pioneer experiments of S. S. Sörensen at Highland Boy and Charles Shelby at Cananea. The mechanical difficulties encountered by them consisted chiefly of two things, viz.: the stoppage of flues with accumulations of ash, and interruptions and irregularities in the coal-dust feed. These were due to insufficient experience in the preparation and fine grinding of the coal, which is absolutely essential to success.

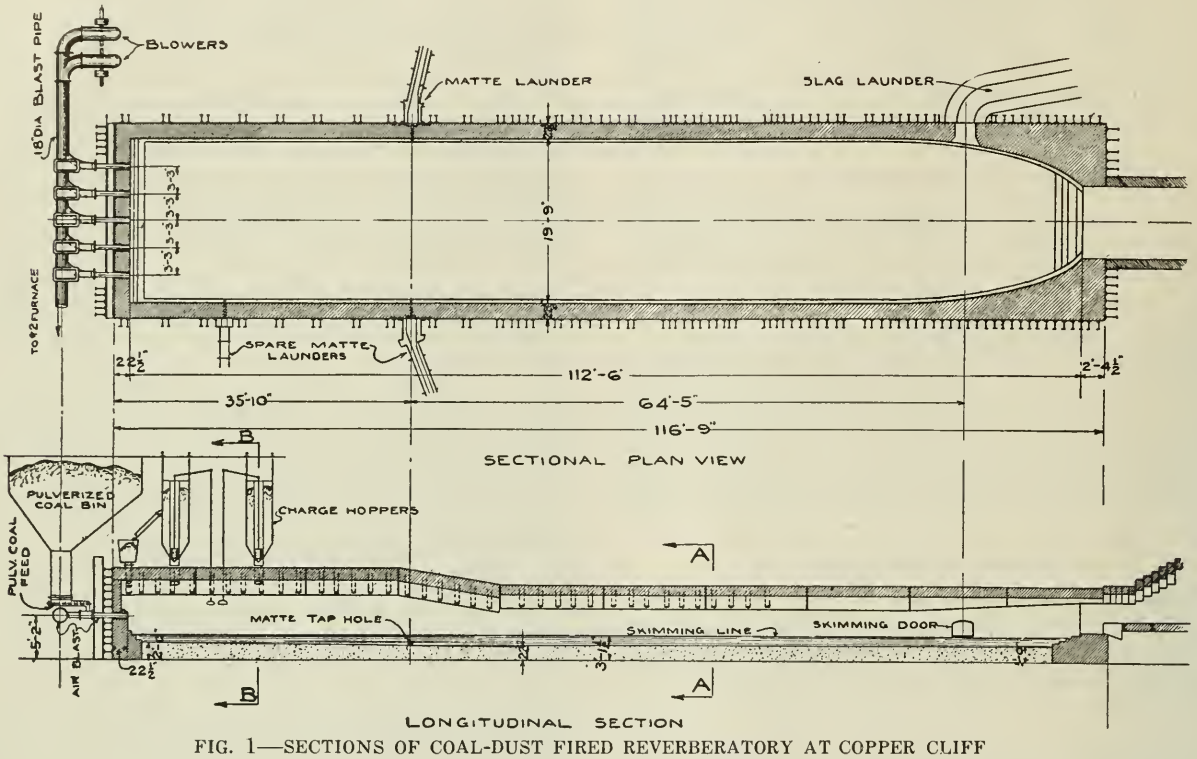


FIG. 1—SECTIONS OF COAL-DUST FIRED REVERBERATORY AT COPPER CLIFF

In April, 1910, the Canadian Copper Co. authorized construction, and work was begun at once. As the entire site of the proposed plant had to be raised 11 ft. above the yard level, and a large amount of rock cutting and filling was necessary on the hillside where the bins and approaches were planned, active construction of the reverberatory proper was slow, and operation did not commence until Dec. 23, 1911.

As built, the original furnaces were lined with basic brick, and the hearth was an inverted arch of magnesite. The furnaces went into operation before any proper means of drying flue dust was provided, and during the winter of 1911-12 a large amount of the charge, wet and frozen as it came from the piles, was shoveled in through the doors of the furnace. All the converter slag was poured in, at first through an opening in the roof, later by means of an iron chute through a door near the fire end, as scrap is charged in an open-hearth steel furnace.

The introduction of so much cold air and cold material prevented any satisfactory fuel ratio. During the first five months 21,406 tons of cold charge and 43,463 tons of converter slag were smelted with 9,609 tons of coal. This shows a ratio of 6.7 tons of total charge per ton of coal, but only 2.2 tons of cold charge per ton of coal. However, as the cold charge was wet and often frozen, better results probably could not be expected.

The combustion of fuel was satisfactory from the start,

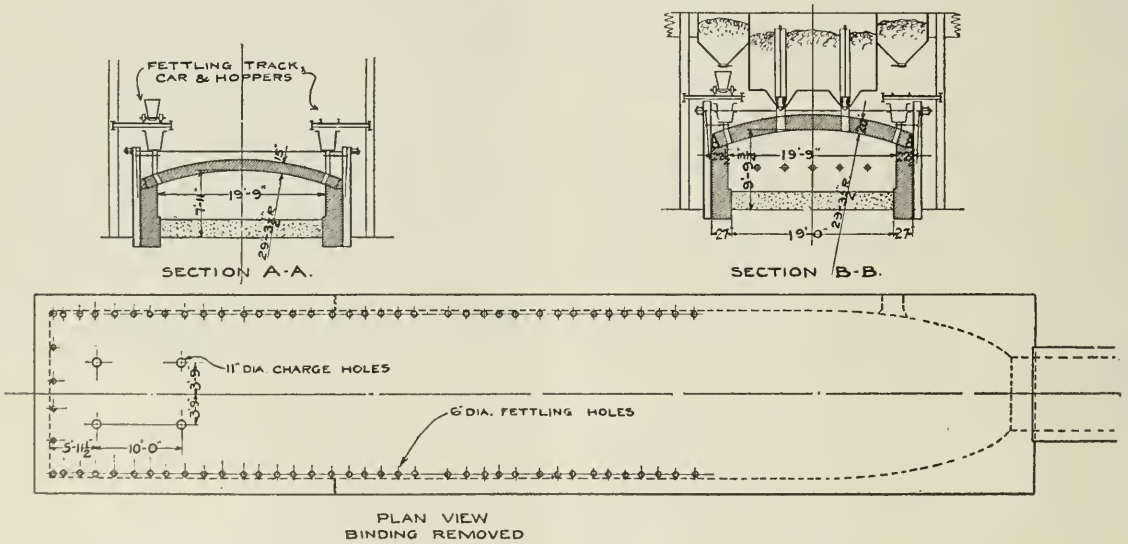


FIG. 2—DETAILS OF THE FURNACE SHOWN IN FIG. 1

no trouble being experienced either in grinding or burning the coal. The ash, while working on cold charges, choked and clogged the flue at the throat. This difficulty was not eliminated until later, when hot calcines were used and a larger tonnage was smelted. In general, the slower the furnace is worked the colder is the ash and the more it sticks and accumulates, while the faster it is driven the less does the ash hang back in the furnace. Under present conditions, with rapid smelting, the ash is a negligible factor.

In the summer of 1912, the roof and side walls were repaired and some facilities provided for drying the charge. In the winter of 1912, four Wedge furnaces were built to roast green-ore fines. These went into operation in March, 1913. At this date we ceased to send converter slag to the reverberatory furnaces, since with the opening of No. 3 mine the blast-furnace charge became more siliceous and slag could be used economically as a flux.

During this year very pronounced improvements were made by Mr. Agnew, then superintendent of the smelter, who with his foremen, Messrs. Kent, McAskill, and Mason, worked out and adapted to our use a modification of the Cananea system of side fettling. Long and shallow pockets were provided along the side walls, and through holes in the roof green-ore fines were fed to protect the sides. This naturally led to bricking up all the doors of the furnace, and the marked improvement which resulted from the exclusion of cold air and the insulation of the walls by a non-conducting and continuously renewed blanket of fines brought about the extension of this side-fettling system to take in almost the entire charge of calcines.

As the walls were thoroughly protected by the charge thus introduced, the use of basic brick in the walls and hearth was no longer necessary, and the next change, in October, 1913, was to the siliceous bottom and silica brick walls customary in Western smelters.

In 1914, the fuel ratio and furnace practice were steadily improving. The figures for the first three months in 1914, one reverberatory being in use, are given in table II.

In the summer of 1914, a change was made in grinding the ore fines for the Wedge furnace. The ore, which was previously too coarse to make a good calcination, was treated in ball mills, and screened, so that only about 14 per cent. remained on a 20-mesh screen, instead of the former 40 per cent. This finer-crushed ore cannot be produced in sufficient quantity to keep the furnace up to its full capacity. Furthermore, when the calcines dropped, on account of this finer grinding of the ore, from 13 per cent sulphur to 7 or 8 per cent, the production of slag increased and the production of matte fell off. These conditions, with shortage of calcines, militated against the high ratio of charge to fuel and in June, 1914, the fuel ratio was 5.35.

TABLE II. RESULTS OBTAINED AT COPPER CLIFF IN 1914

	January	February	March
Furnace days	31	28	31
Calcines, tons	10,020	9,460	10,860
Blast-furnace, flue dust, tons	906	922	847
Wedge-furnace, flue dust, tons	171	193	180
Converter slag	69	248	0
Green-ore fines and samples	1,731	1,326	2,308
Total charge	12,897	12,149	14,195
Coal	2,575	2,150	2,094
Charge per day	416	434	458
Coal per day	83	77	67
Ratio charge to fuel	5.0	5.65	6.77

The second part of Mr. Browne's paper deals with the design and construction of the Copper Cliff furnaces. These are shown in Figs. 1 and 2 on page 182.

The furnace is fed in a rather peculiar way. When the furnace was started almost all the charge was introduced through two charge hoppers near the fire end, as in the usual Western practice. The first hopper delivered through two openings 11 in. in diameter, 7 ft. 6 in. apart and 8 ft. from the outside of the fire wall. The second hopper delivered through two similar openings 18 ft. from the fire wall.

At present almost all the charge is introduced through hoppers along the side walls. Directly over the side walls, at the fire end of the furnace, large bins are provided, which discharge into small bottom-dump cars. These cars run on 24-in. tracks which are supported from overhead. Under these tracks a long trough extends down each side of the furnace just above the side walls. These troughs are filled from the cars on the track above them. Each trough has openings in the bottom, 2 ft. apart, which openings communicate by a slide gate with 6-in. iron pipes. These pipes pass into holes drilled in the roof bricks which allow the charge introduced through these openings to slide down on the side walls, over which this charge forms an almost continuous blanket. As there are no doors on the furnace, and as the 6-in. pipes are clayed into the openings in the roof, it follows that no air is introduced into the furnace except what is purposely introduced at the fire end.

These pipes form a continuous line of charging holes, which extend the entire length of the furnace. The charge on the side opposite the slag door is fed all the way to the throat. On the slag side it is fed along as far as the slag door and no farther, as the cold air coming in while skimming cools the wall from the skim door to the throat and obviates the necessity of charging beyond this point. Six similar openings are used on the fire wall. . . .

The coal dust is introduced through five pipes, 5 in. in diameter. One of these pipes is on the center line of the furnace; the others are in horizontal line with it at distances of 3 ft. 3 in. from center to center. These pipes are 5 ft. 2 in. above the bottom of the sand hearth, or 3 ft. 2 in. above the top of this hearth. They are about 2 ft. above the skimming line of the charge and the central pipe is about 4 ft. 8 in. below the highest point of the roof.

The coal used in firing is a good quality of slack. Analysis of one lot showed: Volatile matter, 34.70; fixed carbon, 55.40; ash, 9.45; sulphur, 1.30; moisture, 4.31 per cent.

This coal has a thermal value of about 13,500 B.t.u. per pound. It is about ¾ in. and under in size and contains about 7 per cent. moisture. It is dried in a Ruggles-Coles drier, 70 in. in diameter and 35 ft. long. One ton of coal burned on the grate dries 40 to 50 tons of slack coal to about 5 per cent moisture, which falls to 2.4 per cent. moisture after grinding. About 10 tons of slack is dried per hour of running time. The coal is ground in Raymond impact mills. About 95 per cent passes a 100-mesh and 80 per cent passes a 200-mesh screen.

The pulverized coal is sucked by a fan to separators above the roof of the drier building, and slides down into a screw conveyor which delivers it into bins at the fire end of the reverberatory. The dust is fed from these bins by Sturtevant automatic-feed screw conveyors, one for each nozzle, the speed of which can be regulated. These screws carry the dust forward and drop it into the air nozzles about 2 ft. from the point where the nozzles enter the furnace. Any coal-delivery pipe can be closed off by a slide gate, and any screw conveyor can be stopped by disconnecting the bevel gears attached thereto. In this way any desired number of the five burners can be run, and at any desired speed within wide limits. The amount of air delivered to each nozzle can be varied at will or cut off entirely.

As a rule the five burners are in operation. Each delivers about 13.5 tons of coal dust a day or about 19 lb. of coal per minute to the furnace. The total coal blown in is about 67 tons a day.

The dust drops from the conveyors into the air pipes which carry it forward into the furnace. The air is supplied by a 4-ft. Sturtevant fan, running at about 1300 to 1400 r.p.m. The air supplied by this fan is insufficient for the combustion of the fuel. Openings are left in the end wall between the coal burners. These openings are stopped by loose bricks, so that the amount of air is readily controlled. The draft at the fire wall is about 0.25 in. of water and at the throat it has a maximum of about 1.2 in. The combustion is very good. One test made for 10 days (Jan. 9 to 19, 1914) showed the following averages:

Coal consumption, tons in 24 hr.	69.7
Gas temperature at throat, degrees centigrade	922
SO_2 and CO_2, per cent.	12.3
Oxygen, per cent.	6.5
SO_3, per cent.	1.14

During this test the average charge was 409 tons in 24 hr. This shows a ratio of 5.9 parts charge to 1 part coal, but much higher ratios have been attained. The average for March, 1914, was 6.84. This coal ratio depends largely upon the composition of the charge and the analysis of the slag produced.

A criticism might be made of the low temperature of the gases at the throat, 922 deg. C. The usual practise in Western smelters is to carry a temperature of 1200 deg. to 1300 deg. at this point, and it might be thought that this low temperature indicated inefficient firing. The fact is that the heat of combustion is utilized in smelting ore along the side walls and consequently the escaping gases, having done more work than is usually the case, are relatively cold. The function of a reverberatory furnace is to melt ore, and not to raise steam, and for this reason the more heat that is absorbed from the coal gases in the furnace, the more efficient the operation and the cooler the escaping gases.

The ash from this coal causes very little trouble in operating. A small amount settles on the slag, but as this slag is high in iron it is not an undesirable feature. A small amount also settles in the flue and a few hundred pounds may stick around the throat. The ash, where exposed to high heat, forms a very light pumice-like fragile mass. The throat is cleaned out daily by opening the door under the flue. During this cleaning the firing is maintained as usual.

The great advantage of coal-dust firing is the absence of the usual breaks in the temperature curve due to grating or cleaning the hearth, and as a consequence a greatly increased tonnage and fuel ratio. The operation of firing, being purely mechanical, comes under the immediate and direct control of the furnace foreman and responds instantly to his regulation. In addition to this, the peculiar method of feeding by almost continuous side charging obviates the breaks in the temperature curve due to charging or ordinary fettling. For these two reasons the chart of the temperature shows an almost horizontal line, rising or falling in almost exact concordance with the speed of the coal-feeding device.

The maximum bath of matte and slag is 22 in. deep. A constant bath of 8 in. of matte is carried. This matte lies 6 in. below the skimming plate, so that after skimming there are 6 in. of slag and 8 in. of matte left in the furnace, making a total minimum depth of 14 in. The skimming door is banked up 8 in. with sand, so that just before skimming the slag is 14 in. deep. As the charge along the side walls occupies a great deal of room there is never at any time more than 40 or 50 tons of slag in the furnace.

In rebuilding this reverberatory, or in designing a new plant, the hearth should be widened to provide for a larger body of matte, which experience has shown to be necessary. As this method of burning coal and of admitting the charge into the furnace bids fair to come into general use it is to be expected that many changes, both in construction and operation, will be introduced. My belief is that reverberatory smelting along these lines will become cheaper than blast-furnace smelting and that a wider range of ores can be used in such a furnace than in the old-style coal or oil-fuel furnaces.

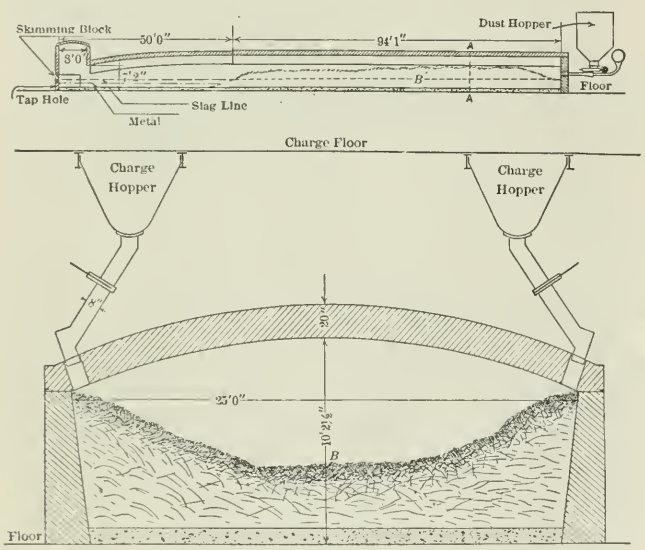


FIG. 3—LONGITUDINAL SECTION AND CROSS-SECTION ALONG LINE AA OF ANACONDA COAL-DUST FIRED REVERBERATORY

Mr. Louis V. Bender's paper deals with "coal-dust fired reverberatories at the Washoe Reduction Works." He describes how after investigating Mr. Browne's work at Copper Cliff, the Washoe Reduction Works decided to experiment with coal dust as fuel in their reverberatories and changed their reverberatory furnace No. 8 to the use of this fuel in June, 1894.

The charging is done on either side of the furnace from longitudinal hoppers, extending a distance of 74 ft. from the back end of the furnace. Leading from the hoppers into the furnace are 6-in. pipes, spaced 19¼ in. apart, through which the charge is intermittently dropped. The charge is kept well above the slag line at all times; in this way the side walls are protected and no fettling is needed on this portion of the furnace. The remainder of the furnace requires fettling. . . .

Conditions which are imperative in order to obtain successful results in coal-dust firing are:

1. The coal, before pulverizing must be well dried, down to 1 cent. or less of moisture. This makes it pulverize better and burn more freely. Nothing is lost in drying it separately, as all the moisture must be evaporated before coal (or any other fuel) will burn, and higher efficiency is obtained when the moisture is driven off before using. The furnace itself is the most expensive place in which to dry the coal, as the effectiveness of the whole fire is lowered by the presence of moisture.

2. The coal must be finely pulverized. The increased surface has a direct bearing upon the efficiency obtained in coal-dust firing. It is well to recognize what this increase is. C. D. Demond, Chief Testing Engineer at the Washoe Reduction Works, says: "The approximate diameter of a 1-lb. lump of bituminous coal is 3 in., and its total surface one-quarter of a square foot, while 1 lb. of coal ground so that 95 per cent. will pass through a 100-mesh sieve and 82 per cent. through a 200-mesh sieve has a total surface of 8000 sq. ft., more or less, depending upon the physical characteristics of the coal, or 32,000 times the area of the single lump."

These figures show that with finer grinding an enormous increase in surface is obtained, and, consequently, an increase in thermal efficiency. At Anaconda the grinding is done so that from 93 to 97 per cent. will pass through 100 mesh and 79 to 82 per cent. through 200 mesh. . . . The standard of approximately 85 per cent through 200 mesh and 95 per cent through 100 mesh is a practicable commercial standard and should be maintained.

3. The delivery of the coal and air to the furnace must be controlled so that the proper quantities of each may be secured. Undoubtedly, the proper method of firing pulverized coal is to admit with the fuel the exact quantity of air required for the results to be attained, and to maintain this relationship as long as results wished for are obtained. We know that in order to get the best heat efficiency from fuel a certain amount of air must be provided for combustion. Any air in excess of these requirements dilutes the gases and lowers the temperature; and insufficient air will burn part of the fuel to CO_2 and part of it to CO, which means incomplete combustion.

4. The coal must contain enough volatile combustible matter to give the required combustion. In cement work coal containing as low as 22 per cent. V.C.M. has been used. James Lord, of the American Iron & Steel Co., recommends 30 per cent as a minimum.

5. The furnace must be properly proportioned, properly equipped, and in good condition.

6. Provision must be made for taking care of the ash formed.

The powdered-fuel equipment at Anaconda is then described and the advantages of powdered-fuel firing are summed up as follows:

1. An increase in tonnage, which makes it possible to smelt the necessary tonnages with fewer furnaces.

2. The efficiency of this method is much greater than that of burning coal on grates. In burning coal on grates, there is a loss in transferring to the hearth the heat generated in the fire box. This does not occur in coal-dust firing, where the combustion occurs over the hearth itself. Another point is that none of the heat is lost in gratings from the fire box. In our practice of grate firing, this loss amounts to something like 10 per cent of the fuel values. The efficiency is greater, due to a uniform temperature being maintained. There are no fluctuations in temperature due to firing cold fuel or to grate cleaning, or to the personal equation of the men firing the furnace.

The superintendent before leaving his work can adjust the feeding of the coal, and by securing this adjustment with a padlock he can be certain that a definite amount of coal will be burned during his absence. If, for any reason, the furnace men need to shut off the burners, they can do so by releasing a clutch; when this clutch is re-engaged, the burner resumes firing at the original adjustment.

3. Higher temperatures than usual can be produced and maintained because the quantity of coal burned can be easily increased, and also, because there is less excess air to be heated. In grate firing 100 per cent excess air is used, while in dust firing only 25 per cent excess air is required. There being a smaller volume of gases, they will remain longer in the furnace, and, consequently, give up more heat to the charge.

4. Less draft is required because there is no bed of coal through which air is drawn. This is an advantage in that less cold air is drawn into the furnace through the side walls.

Details are given of the results of tests made in September, 1914. The fuel ratio was 7.19 (excluding drier coal) and 7.08 (including drier coal). The ash gave very little trouble.

"The efficiency of this method of firing is improving

so rapidly that a paper is almost out of date before it can be read. New records for tonnage and fuel ratio are made almost every day. The average tonnage per day for the past week was 542.7, with a fuel ratio of 7.50."

The paper by R. E. H. POMEROY, of McGill, Nev., was next presented in abstract, dealing with the "reverbaratory smelting practice of the Nevada Consolidated Copper Co." California crude oil is used as fuel. The results are excellent. A longer abstract of this interesting paper is reserved for our next issue.

These papers were discussed together and the discussion was lively and extended. Mr. Mathewson read from a telegram the latest results achieved in Anaconda.

A communicated discussion described the results obtained at the smelter at Garfield, Utah.

Mr. J. B. Herreshoff paid a fine tribute to the bigness of Western smelters, Western men, and Western open-heartedness and gave details of a big reverberatory (with grate firing) in an Eastern copper plant.

Mr. Klepetko suggested that the excellent results obtained were due perhaps more to the charging on the sides than to the use of pulverized coal. While the charging on the side is an important factor, Dr. J. W. Richards pointed out that there is no getting away from the fact that in a grate-fired furnace 25 per cent of the calorific value of the fuel is lost from the fire place; this loss is wiped out by the use of powdered coal.

Mr. Mathewson stated that with their big new reverberatory the expectations were to realize a tonnage of 750 per day with a fuel ratio of 7½. He also exhibited a brick made from the flotation tailings of slimes at Anaconda (70 per cent silicon, 21 or 22 alumina, 1 sulphur, 0.8 lime) and predicted a big future for this brick.

Mr. D. H. Browne emphasized again in his modest way that most of the Copper Cliff success had been due to the work of "the boys" at the smelter.

In the afternoon of Wednesday there was a session devoted to papers on mining and the application of electricity in mines. On the same afternoon a visit was paid by members and their ladies to the Art Galleries of Senator W. A. Clark.

The seventeenth annual meeting of the **Canadian Mining Institute** will be held at Toronto, March 3, 4 and 5, 1915. Headquarters will be at the King Edward Hotel. The provisional program contains some excellent papers relating to mining and metallurgy in Canada.

The **Calumet & Hecla Mining Co.** has just completed the installation of 12 large Hardinge mills in its new White Pine concentrator. Three Hardinge ball mills of the largest size are to be installed in the plant of Moose Mountain, Ltd., at Sellwood, Ontario, Canada.

Messrs. **Chalmers & Williams**, of Chicago Heights, Ill., announce that they have taken over the exclusive rights of manufacture and sale of the Symons disc crushers, Symons fine reduction disc crushers and Symons pulsating screen.

The **Snyder Electric Furnace Company** is the new name of what was formerly the Metallurgic Engineering Company. The business of the company is largely devoted to the building of the Snyder type of electric furnace. Mr. F. T. Snyder is the president, Mr. Carl H. Book, vice-president; Mr. W. K. Booth, secretary, and Mr. F. E. Berggren, treasurer of the company. The office is at 53 West Jackson Boulevard, Chicago, Ill.

The **American Electrochemical Society** will hold its spring meeting from Thursday to Saturday, April 22 to 24, at Atlantic City, N. J.

Recent Chemical and Metallurgical Patents

Iron and Steel

Sintering Apparatus.—Improvements in apparatus for sintering fine iron ore are embodied in a patent granted to STEPHEN A. KROM, of Birmingham, Ala. The invention relates to sintering apparatus of the pan type, in which a charge of ore is ignited and sintered and then dumped by tilting the pan. The object of the improvements is to secure equalization of draft and uniform ignition, and to prevent the accumulation in the bottom of the pan of fine material falling through the grate bars. To this end the pan is constructed with a conical bottom. From the apex of the cone a connection is made by pipe with a tank or receiver; the exhaust fan is connected with the pipe between receiver and sintering pan. The pan is fitted with an air-tight cover, through which the gas burner tubes extend over the surface of the charge from a main or header outside. By this construction even ignition is secured over the surface of the charge, and the suction is uniform by reason of the fact that it is taken from the apex of the cone bottom. Fine particles of ore falling through the grate are directed by the conical bottom and connecting pipe to the tank or receiver. (1,125,125, Jan. 19, 1915.)

Iron-Boron-Carbon-Copper Alloy.—An alloy that is practically non-corrosive and which can be rolled and machined without being annealed, is patented by EDWARD D. GLEASON, of New York City, the patent being assigned to the Neu-Metals and Process Company, of Long Island City, N. Y. The boron is first incorporated in the copper, the boron being in excess of the quantity that will combine with copper, and this boron-copper is added to low-carbon steel. (1,126,629, Jan. 26, 1915.)

Gold and Silver

Slime Filter.—An improvement in vacuum filters or pans of the tray type is patented by WALTER E. TRENT, of Reno, Nev. A transverse vertical sectional view of the apparatus is shown in Fig. 1. It consists of two oblong trays 1 and 2, supported apart as shown and adapted to be turned on a trunnion 8′. Suitable connection is made between the filter frames resting in the pans and a source of vacuum. The filter frames consist of pipes 16 and 16′ perforated as shown in 16². The slime to be treated is delivered to hoppers 11 and thence by pipes which are extending over the surface of the filters. Water spray pipes 20 and 20′ are placed as shown. In operation the slime is delivered to the filters and the liquid drawn from the solids, leaving the latter as a cake on the filter surface. Water is then admitted through the spray pipes to lubricate the filter surface so that the cake will slip from the filter when the apparatus is tilted. (1,125,769, Jan. 19, 1915.)

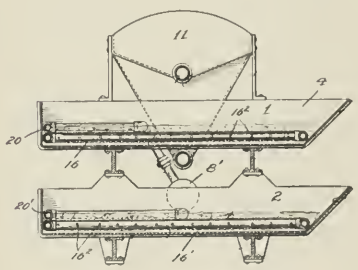


FIG. 1—SLIME FILTER

Precipitant for Gold and Silver in Cyanide Solutions.—A brittle alloy of zinc and sodium, or zinc and any other alkali or alkaline earth metal which will produce brittleness in the resulting alloy, is patented by G. HOWELL CLEVENGER, of Palo Alto, Cal. The patent is assigned to the Merrill Metallurgical Co., of San Francisco, Cal. The alloy thus produced by adding about three per cent sodium to zinc, can be comminuted and used in place of the other forms of zinc

now common in the precipitation of precious metals from cyanide solutions. (1,123,685, Jan. 5, 1915.)

Method of Precipitating Cyanide Solutions.—A method of combining the operations of precipitating and filtering cyanide solutions containing precious metals, is patented by Louis D. Mills, of Johannesburg, Transvaal, South Africa. The patent is assigned to the Merrill Metallurgical Co., of San Francisco, Cal. The apparatus and method is illustrated in Fig. 2. A tank 1 contains filter leaves 2 disposed vertically in the usual manner and having connections with a pump 4 or other means for exhausting the interior of the leaves. The receptacle 14 is for pregnant solution and the apparatus 13 is a feeder for zinc dust or other mobile precipitant to be mixed with the solution. The solution and precipitant are both delivered into the hopper 9 which is mounted on a revolving shaft 8. From the hopper the mixed solution and precipitant flow through pipes 6 having apertures 7. These pipes also revolve with the shaft and hopper, and provide means for uniform distribution of the mixture above the filter leaves. For the purpose of circulating the solution and precipitant and preventing the accumulation of solid matter in the bottom of the tank, a series of rakes 22 is mounted at the bottom of the shaft 8, similar to the mechanism of a Dorr thickener, and in the course of their revolutions they move any solids toward the central discharge point 20, whence solution is pumped back to the hopper as shown. In operation, the exhaustion of the leaves by the pump 4 causes a cake of precipitate to form on the leaves, and the solution passing through this cake is subjected to precipitating action. When it is desired to recover the cake, the supply of fresh solution is shut off, the pump 4 stopped and the precipitate sluiced from the leaves. It can then be removed from the tank by the pump 11 and pipe 23. (1,123,778, Jan. 5, 1915.)

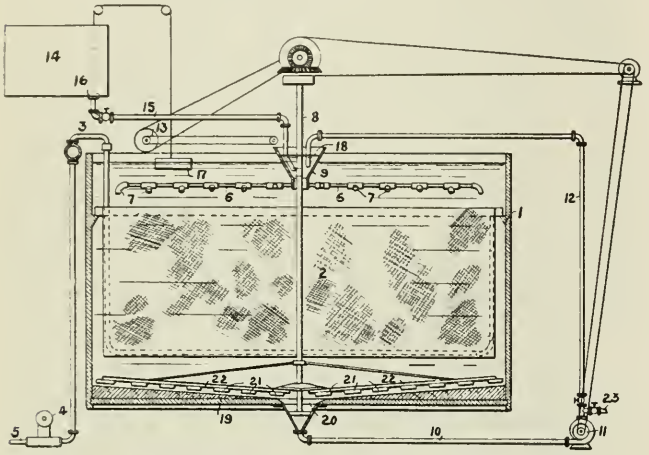
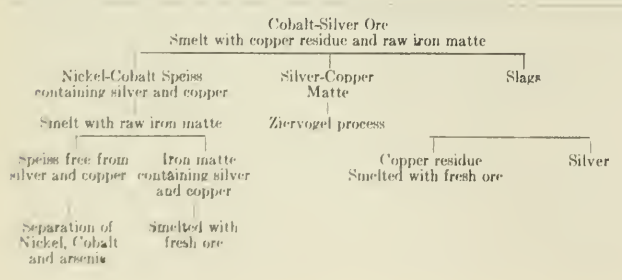


FIG. 2—PRECIPITATING APPARATUS

Treatment of Cobalt-Silver Ores.—According to a process patented by William Phillips, of Swansea, Wales, cobalt-silver ores can be treated for the recovery of silver, nickel, cobalt, copper and arsenic. An outline of the process is given below.


Cobalt-Silver Ore
Smelt with copper residue and raw iron matte
Nickel-Cobalt Speiss containing silver and copper
Silver-Copper Matte
Slags
Smelt with raw iron matte
Ziervogel process
Speiss free from silver and copper
Iron matte containing silver and copper
Copper residue Smelted with fresh ore
Silver
Separation of Nickel, Cobalt and arsenic
Smelted with fresh ore

The first step is performed in a reverberatory furnace. About 82 per cent of the silver in the ore passes into the copper matte, and about 17 per cent into the speiss. Also about 16 per cent of the copper passes into the speiss. The silver-copper matte will contain between 2000 and 3000 oz. silver per ton and about 25 per cent copper. The silver is extracted by the Ziervogel process.

The first raw speiss is smelted in a reverberatory with raw iron matte, the operation being repeated several times. About 60 per cent of the silver goes into the iron matte in the first smelting. (1,127,506, Feb. 9, 1915.)

Copper and Tin

Electrolysis of Copper Solutions.—A process of electrolyzing copper solutions containing iron, without first reducing the iron to the ferrous state, is patented by N. V. Hybinette, of Christiania, Norway. He makes use of a cell containing a diaphragm separating the anode from the cathode. A continuous flow of solution is maintained on the anode side only, and the solution on the cathode side is effected only by such changes as can be transmitted by diffusion. The solution on both sides of the diaphragm may, in the beginning of operations, contain 20 g. of iron as ferrous sulphate, 40 g. iron as ferric sulphate, 40 g. copper as sulphate and 50 g. free acid. When the current is applied the iron in the cathode is reduced and copper begins to plate. If then the solution on the anode side is continuously circulated so as to maintain a uniform composition, the solution on the cathode side will automatically adjust itself to contain say, 55 g. ferrous iron and 20 g. copper. The inventor states that "without any apparent reason copper is entering the cathode compartment, while ferric salts do not enter and the electric energy is therefore used to deposit copper and not to reduce ferric salts." With a concentration of solution mentioned, he uses a density of 10 amperes per sq. ft., and obtains an efficiency of nearly 90 per cent. The voltage is approximately 3. In Fig. 3 is shown a cell for this work; B is the anode and C the cathode, the latter being enclosed in a diaphragm formed of a double-walled leaden screen D secured to a wooden frame K which is filled with asbestos or other porous material. The electrolyte flows in at F and out at G. (1,123,299, Jan. 5, 1915.)

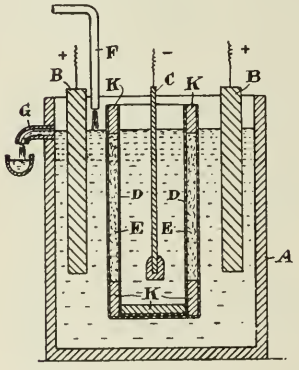


FIG. 3—ELECTROLYTIC CELL

Purification of Copper.—A method of producing pure copper for electric purposes and for the manufacture of copper-clad metals is patented by Wm. M. Page, of Philadelphia, and Wirt Tassin, of Chester, Pa. It consists in deoxidizing molten copper at a high temperature by the addition of iron or steel, and later removing the excess of iron by covering the bath with carbon. This has the effect of blanketing the bath with oxides of carbon, both of which are oxidizing to iron but not to copper. The copper, after purification, is cast under conditions which preclude oxidation during the pour. In making copper-clad metal, the metal to be treated is prepared in a special manner and then dipped in the copper. (1,125,164, Jan. 19, 1915.)

Sulphatizing Roast for Copper Ores.—The conversion of copper sulphide into sulphate for purposes of leaching the soluble copper salt, is usually accom-

plished by roasting under certain conditions. According to a patented process of A. D. CARMICHAEL, of West Norfolk, Va., this sulphatizing can be accomplished by first heating the ore out of contact with the air to a temperature between 500 deg. and 700 deg. C., at which temperature the formation of iron sulphate will be avoided, and then exposing the heated ore to air, preferably heated. One advantage claimed is the production of more concentrated sulphurous acid gas, suitable for making sulphuric acid, than can be made by ordinary roasting processes on low-sulphur ores. Other advantages lie in forming no iron sulphate, or in rendering iron insoluble. (1,124,696, Jan. 12, 1915.)

Copper Converter.—An improved form of converter is patented by HERBERT HAAS, of San Francisco, Cal., having for its object the converting of mattes into blister copper continuously instead of intermittently as in present methods. As shown in Fig. 4, the converter consists of a shell lined with magnesite brick. The bottom comprises a central inverted cone or bell portion and a depressed annular portion. In the center of the cone is the tuyere block in which are formed tuyeres that are directed upwardly, outwardly and preferably tangentially. A tap-hole is placed at the level of the depressed annular portion for the removal of molten copper, and an upper tap-hole for the removal of slag. The tuyeres are greater in number, but of smaller cross-section than those in ordinary converters, thus affording more efficient use of air. The function of the depressed annular portion is to store reduced, molten copper and remove it from the action of the blast. (1,123,868, Jan. 5, 1915.)

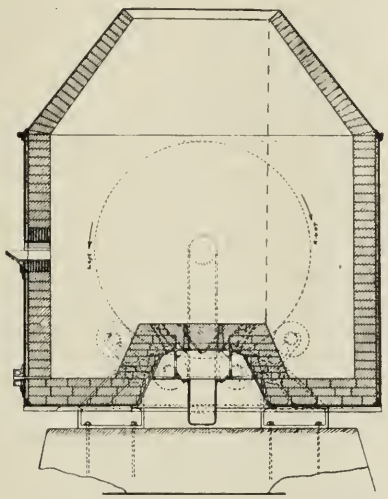


FIG. 4—COPPER CONVERTER

Electrolytic Refining of Tin.—A process of electrolytically refining tin, patented by GEORGES MICHAUD and EUGENE DELASSON, of Montreuil, France, consists in passing a current from an anode of impure tin to a cathode through an electrolyte composed of 100 parts by weight of tin protochloride, 10 of sulphuric acid, 1 of madnesium chloride and 1 of boric acid, mixed with water to make a solution of 20 deg. Baume. The cathodes are formed by copper plates arranged on edge, and upon the upper edges of which the tin is deposited in non-adhesive form and mechanically removed. The homogeneity of the electrolyte is maintained by circulating it through a trough containing tin waste of any kind. The inventors claim that the process will produce 2.22 grs. of chemically pure tin per ampere hour in a more economical manner than with arrangements ordinarily used. (1,124,315, Jan. 12, 1915.)

Uranium, Vanadium and Radium

Treatment of Carnotite Ores.—A method for treating complex carnotite ores for the recovery of uranium, vanadium and radium is patented by CHARLES W. DANFORTH, of Youngstown, O.; WILLIAM P. SAMUELS, of New Castle, Pa., and WILLIAM T. MARTERSTECK, of Youngstown, O. The method consists in giving the ore an oxidizing roast, then adding sulphuric acid to precipitate barium and radium into the residue and dissolve uranium and vanadium. The solution is separated by filtration. The ore is ground to about 40-mesh and roasted in an oxidizing atmosphere at a temperature of 1100 deg. F. for about an hour. The addition of sulphuric acid is said to dissolve about 90 per cent of the vanadium and all the uranium, leaving the barium and radium as sulphates with the sandy residue. To recover the radium, the residue is washed free from acid and treated with a solution of caustic soda and sodium carbonate. This changes the barium and radium compounds into carbonates. The mixture is then filtered and washed, leaving the barium and radium still with the residue. The addition of hydrochloric acid then dissolves the barium and radium. The solution is removed and precipitated with sulphuric acid, the sulphates separated and again converted into chlorides, after which the radium is concentrated by crystallization.

Synopsis of Recent Chemical and Metallurgical Literature

Iron and Steel

Magnetic Habits of Alloy Steels.—There is a certain relationship between the magnetic and physical characteristics of steel and its alloys, distinct similarity between their magnetic and physical behavior. Dr. J. A. MATHEWS, in a very interesting paper (*Proceedings*, American Society for Testing Materials, Vol. XIV, 1914) brings out some interesting new relations and remarks justly that the fascination of magnetic investigations lies in the frequency of unexpected results. He suggests a new magnetic unit of magnetic hardness B_r/H_c; that is, the ratio between residual density and coercive force is used to indicate magnetic hardness in a way similar to the use of μ to indicate permeability. Dr. Mathews discusses the relation between hardness as measured by the Brinnel and Shore methods and magnetic hardness as indicated by B_r/H_r. In hardened alloy steels the magnetic properties vary with the cross-section, but in some cases, the magnetic hardness increases as the section increases while in other cases the reverse is true, and in some alloy steels either condition may be had, depending upon the manner of quenching. Many alloy steels give lower induction, lower residual density and higher coercive force when quenched in oil than when quenched in water; the corresponding physical hardness test showing, as would be expected, that the water quenching confers the greater hardness. The effect of drawing the temper of hardened alloy steels is discussed and it is shown that for equal drawing temperatures the magnetic properties of oil-hardened pieces are most affected, while as to the physical hardness the water-hardened pieces are affected to the greater degree.

Gold and Silver

Metallurgical Practice in the Porcupine District.—In a paper presented at the New York meeting of the A. I. M. E. last month, Mr. NOEL CUNNINGHAM, formerly mill superintendent for the Hollinger Gold Mines, Ltd., discusses the metallurgical technology of Porcupine district ores. His notes supplement milling articles of a descriptive nature, such as appeared in METALLURGICAL AND CHEMICAL ENGINEERING in September and October 1914.

There is no oxidized ore in the district. The precious-metal content is about in the proportion of 85 of gold to 15 of silver by weight. Two classes of ore are distinguished: *Class A*, which is pure quartz with inclusions of schist, containing free gold which is 60 per cent. to 85 per cent. free-milling, spongy and readily soluble in cyanide solution. *Class B*, which is an iron

silicate schist, contains 4 per cent. to 5 per cent. pyrite. This ore produces in grinding a comparatively large amount of non-crystalline slime which is quick settling. The gold is free, but so fine that it will neither amalgamate nor pan; it is disseminated through the rock and not chiefly associated with the pyrite.

After giving a brief outline of the mills, past and present, in the Porcupine district, the author analyzes milling practice and makes some comparisons of methods. In regard to stamps vs. ball mills as crushers preliminary to tube-milling, the author is of the opinion that ball mills are preferable on Porcupine ore. On the subject of stamping in water and amalgamating vs. stamping in solution without amalgamation, the author compares Dome and Hollinger practice, respectively:

"The advantages claimed for stamping in water and amalgamating are a better recovery of the coarse free gold and the saving in treatment cost, due to a smaller amount of solution to precipitate and a smaller amount of precipitate to handle. At first sight it would also appear that a saving in dissolved losses from the filters would be made, owing to the smaller amount of gold in solution going to the filters.

"While at the Hollinger there is a smaller percentage of amalgamable gold in the mill heads than at the Dome, on the other hand, the coarse free gold per ton of ore in the mill heads is about the same due to the fact that the head assay is nearly triple that of the Dome. Hence, if amalgamation is necessary in order to assure the dissolution of coarse gold in cyanide solution, difficulty from this source should be experienced at the Hollinger, where crushing is in solution with no amalgamation.

"This is not the case, however; all the coarse gold goes into solution in the classifier-tube mill closed circuit. This is proved by two facts in connection with the Hollinger operations. Table concentration after fine grinding is practiced at the Hollinger, and any coarse free gold passing the tube mill-classifier closed circuit would be caught on the tables. No coarse gold is present in table concentrates, however, no color of free gold ever showing on the tables; also practically no amalgam was produced (under 1 per cent. of the total values recovered) during six months, pan-amalgamation of concentrates from the tables.

"Facts also indicate that crushing in solution without amalgamation has the best of the argument in regard to amount of solution precipitated and dissolved gold mechanically lost. With the head assay at the Hollinger about three times as high, the precipitation ratio is only about twice that at the Dome, and the mechanical loss of dissolved gold and cyanide only about one-half. Nor is any saving in dissolved losses or treatment cost proved in favor of crushing in water followed by amalgamating. On the other hand, there are added to the treatment cost, (1) cost of amalgamation, (2) cost of increased cyanide consumption due to 'waste' solution precipitated and thrown away, and (3), in winter, the cost of heating to mill temperature the quantity of water—equaling several times the weight of ore treated and introduced at nearly a freezing temperature—to replace the water and waste solution discharged with the tailing, which would not be necessary if crushing were done in solution. The loss of gold left in 'waste' solution after precipitation must also be added to the cost.

"In comparing Dome and Hollinger metallurgical practice, it is only fair to state that since the Dome ore is harder and more compact, the gold may be less spongy and therefore less amenable to cyanidation. The only deduction which can be drawn from the facts, as far as I know them, is, that apparently in treating average- and low-grade ore of the district amalgamation can be eliminated; that if amalgamation is eliminated and solution introduced at the stamps, a considerable saving in operating cost, cyanide, and dissolved gold losses is possible.

"Unquestionably more extensive study has been given to the treatment of the Dome ore than to any other in the district. Hence one hesitates to make what may appear to be a criticism of an operating system probably justified by a careful balancing of co-ordinate factors by an eminent firm of metallurgists. However, no metallurgical discussion would be complete without touching upon this point, which is the salient difference between the two metallurgical systems of the district."

On the subject of concentration vs. non-concentration, it is Mr. Cunningham's opinion that concentration warrants careful consideration on the score of being able to give a portion of the ore the special treatment it demands instead of subjecting the entire ore to treatment necessary for only a part of it.

For agitation, the author considers the Dorr agitator well adapted to the treatment of the quick-settling and granular slime, particularly on account of being able to give selective agitation to a part of the ore requiring longer treatment. As to filters, pressure filters will be found more satisfactory than vacuum on account of the quick settling nature of the ore, causing difficulty in maintaining a pulp of uniform density and giving rise to uneven and channeled cakes. Continuous decantation is regarded as specially applicable to Porcupine ores, without the use of filters.

Zinc

Concentration at the Timber Butte Mill.—In a paper read before the Montana Society of Engineers, Butte, Mont., Mr. Theodore Simons described the concentration process used at the Timber Butte mill in treating the zinc ores from the Elm Orlu mine. The mill site on the northern slope of Timber Butte affords the following advantages: gravity system of ore flow; extensive area for tailings; good water supply and transportation facilities. The ore contains zinc and lead as sphalerite and galena; copper as bornite, chalcocite, tennite and tetrahedrite; gold and silver free and chemically combined with the base-metal sulphides. The gangue is quartz, barite, fluorite, rhodonite and rhodocrosite. Iron occurs as pyrite. Lead occurs in small quantity only, 0.75 per cent., and consequently a large expense for its recovery is not warranted. Moreover it is intimately associated with zinc and other sulphides so that a separation is difficult. The percentage of iron is 3.29, and of zinc 18.52. In order to make a satisfactory recovery of the lead and iron it is necessary to enrich those products at moderate cost and get something that will stand further refinement. This is accomplished by Wilfley roughing tables. These tables also recover from 25 per cent. to 30 per cent. of the total zinc in the ore at small cost. With the exception of this roughing operation, the only other gravity separation of mineral is performed on James tables that retreat the coarse part of the finished flotation product. Otherwise, all concentration is by flotation. The capacity of the mill is 450 tons of ore per 24 hours. The ratio of concentration for zinc is 3:1, and for lead-copper-iron, 125:1. Extraction averages about 96 per cent. of the zinc and 92.6 per cent. of the silver.

The striking feature in the gravity-concentration section of the mill is the operation of the Wilfley roughing tables, so-called. They are the first concentrating machines encountered in the mill, and take the undersize from impact screens without any previous classification. The tables not only handle an unusual quantity of material, amounting to more than 100 tons per table,

but they make at the very outset a finished coarse-zinc concentrate, containing from 49 to 51 per cent. zinc, and not more than 4 per cent. insoluble. They also send all the fines coming from the mine and those made in the preceding crushing operations to two Akins classifiers to be separated from the tailings, after which they go directly to the Minerals Separations flotation section, where they belong. Thus none of the intermediate machines is encumbered with this troublesome material, and the losses incident to frequent handling of slimes are reduced to a minimum. All this is accomplished by a clever modification and distribution of the riffles by giving the tables a rather steep inclination (8 deg. to 10 deg.) and by adding the proper amount of wash water.

To unlock the finest included grains of sulphides from the adhering gangue, prior to separation, it is necessary to crush the Elm Orlu ore to between 40 and 60-mesh, maximum. It was found that to attempt to extract zinc from material finer than 40-mesh by gravity concentration gave a low grade of concentrates, and would require a costly installation. This led to the adoption of flotation, according to the process of the Minerals Separation Co. The pulp is kept at a uniform density in the proportion of 3 of water to 1 of ore, and is heated to a temperature of 130 deg. F. by the introduction of live steam. From tests it appeared that with the Elm Orlu ore higher temperatures did not produce better results, while temperatures below 125 deg. reduced the efficiency of the plant.

Sulphuric acid is mixed with the pulp at the rate of 7 to 8 lb. to every ton of original ore going through the mill. Oil is added in the proportion of 0.5 of a pound per ton. Oil is introduced in the mixing compartment of the first cell where the pulp is violently churned by the action of the agitator, which at this plant makes 265 r.p.m. and causes the propeller to run at a peripheral speed of about 1500 lin. ft. per minute. The aerated mixture passes through an opening into the flotation compartment, where the froth containing the sulphides of lead, copper, zinc and iron, as well as some of the richer middlings, immediately rises to the surface while the clean gangue and the leaner middlings drop to the bottom.

The flotation compartment has the shape of a spitzkasten, the apex of which is provided with a valve, adjustable by a handwheel. Through this valve the material that has settled to the bottom of the first cell is drawn into the adjoining cell by the pumping action of its propeller. The process is here repeated, and the sulphides which did not float in the first cell are given a chance to do so in the second, and so on. By the time the pulp has reached the seventh cell of the rougher machines the clean sulphides and the richer middlings have all been floated. The remaining middlings in their passage from cell No. 7 to cell No. 11 are separated from the tailings by the successive flotation of the middlings, until in the bottom of the last cell only clean tailings remain, which are taken to a Dorr thickener for extraction of the hot water. This is pumped to a tank to be reused in the flotation machines. The middlings overflowing from the cells Nos. 7 to 11 are reground in the Hardinge mills and returned to the flotation section.

The float concentrates from the first six cells of the rougher machine is a product rich in zinc (about 47.8 per cent.), but due to the presence of middlings still contains about 14 per cent. insoluble. It is therefore sent to the first and fifth cells of a 200-ton Minerals Separation flotation unit containing eight cells. This is known as the "finisher machine," because it makes a finished sulphide concentrate. On passing the pulp through the successive cells of the finisher the sulphides are floated to the surface, while the clean middlings ultimately reach the bottoms of the fourth and eighth cells, whence they go to Hardinge mills, to be reground and returned to the flotation section.

The float concentrates from cells Nos. 1, 2, 3, 5, 6 and 7 of the finisher machine is a finished sulphide product containing, besides the sulphides of lead, copper and iron, 52 per cent. of zinc and 3.5 per cent. insoluble. The fines in this product overflow as fine zinc concentrates from an Esperanza and a Richards classifier through which the product is passed, the coarser portion of which is retreated on James tables. On these tables the lead and iron are separated from the zinc, and the insolubles in the zinc concentrate are reduced to 3.5 per cent.

The overflow from cells Nos. 4 and 8 of the finisher machine, being apt to contain a varying amount of middlings, is returned by air lift to the same machine. The agitating compartments of the flotation cells are lined with cast iron, and the propellers are made of brass. All agitators of a standard machine are driven from one main shaft by gears, which are protected from dust by steel housings. Gears are placed so that propellers in adjoining cells revolve in opposite directions, thus equalizing the strains on the machines and power transmission.

X-Ray Examination of Metals

Use of the Coolidge X-Ray Tube in Metallurgy.—In the General Electric *Review* for February, 1915, Dr. WHEELER P. DAVEY describes the use of the Coolidge tube in observing the defects of cast metal. Copper cast without the addition of boron gives a radiograph showing the pores in the metal, while a radiograph of boronize copper is without spots. The radiograph can be made by a two-minute exposure, the current through the tube being 2.8 milli-amperes and the potential difference across the tube corresponding to a 10-inch parallel spark gap between points. The advantage of the radiograph in experimental work is obvious, as it permits the determination of defects without machining the metal or destroying the casting. It is possible, also, to make stereoscopic radiographs, showing defects in their entirety and estimating their depth. A wide field for further work is opened by this use of the X-ray tube.

Instruments

The Measurement of Rapidly Changing Temperatures is the subject of a discussion by ALFRED PETERSEN (*Zeit.* d. Ver. Duetsch. Ing., April 18, 1914; in abstract in *Bulletin* de la Soc. d'Encouragement, Aug.-Sept.-Oct., 1914, p. 328). To follow instantaneously the changes of temperature, for instance, in the cylinder of an internal-combustion engine, an electrical instrument must be used, either a thermocouple (platinum, platinum-rhodium) or an electric resistance pyrometer (platinum-iridium, containing 35 per cent iridium). For measuring the current an Einthoven string galvanometer is used, for calibration of the thermometers an electric furnace. Some experiments were made under what conditions variations of 1800 deg. C. during one-tenth second could be measured. For this purpose the thermo-element or resistance wire were mounted on a revolving disc, so as to carry them at the proper intervals through a Bunsen flame. Only thermo-couples of 0.02 and 0.03 millimeter or resistor wires of 0.02 millimeter reached the temperature to be determined in this time, and only the resistance pyrometer completely recovered its original temperature at the end of one-tenth of a second.

Table I

Experiment No.	5	6	7	Average
Battery	5 Stamps	5 Stamps	5 Stamps	....
Weight of stamps in lb.	1300	1300	1300	1300
Drops per minute	103.5	106	103.3	104.27
Average height of drop	7.8 in.	7 in.	7.5 in.	7.43 in.
Hp. at motor	17.12	16.2	16.92	16.75
Hp.—"Actual" from weight stamps × drops per min.	13,25	12.18	12.72	12.72
Percentage actual of motor hp.	77.3%	75.2%	75.2%	75.9%
Screening used	12 = 8 I.M.M.	30 = 22 I.M.M.	30 = 22 I.M.M.	....
Lb. ore crushed per minute	44.7	33.8	31.04	36.51
Lb. water used per minute	474	472	405	450
Average temp. C. of ore, feed	22.15	24.2	22.0	22.783
Average temp. C. of water, feed	27.07	27.96	26.51	27.180
Average temp. C. of pulp, dis.	27.483	28.372	27.00	27.618
Diff. temp. ore, feed and discharge	5.333	4.172	5.00	4.835
Diff. temp. water, feed and discharge	0.413	0.412	0.490	0.438
Heat units from ore, S.H. = 0.251	44.7 × 0.251 × 5.333 = 59.83	33.8 × 0.251 × 4.172 = 35.39	31.04 × 0.251 × 5.00 = 38.95	36.51 × 0.251 × 4.835 = 44.49
Heat units from water, S.H. = 1	474 × 1 × 0.413 = 195.76	472 × 1 × 0.412 = 194.46	405 × 1 × 0.490 = 198.45	450 × 1 × 0.438 = 197.10
Total increase in heat units per minute	255.59	229.85	237.40	241.59
Hp. represented by heat units as $\frac{\text{H.U.} \times 1390}{33{,}000}$	$\frac{255.59 \times 1390}{33{,}000}$ = 10.76 hp.	$\frac{229.85 \times 1390}{33{,}000}$ = 9.68 hp.	$\frac{237.4 \times 1390}{33{,}000}$ = 9.999 hp.	$\frac{241.59 \times 1390}{33{,}000}$ = 10.170
Percentage motor hp. returned as heat	62.84%	59.7%	59.09%	= 60.7%
Percentage actual hp. returned as heat	81.2%	79.5%	78.6%	79.95%
Size of ore before milling	— 2 in + ¾ in. ring	— 2 in. + ¾ in.	— 2 in. + ¾ in.	....
	%	%	%	....
I.M.M. Mesh after milling.. — 8 + 30	36.12	....	....	....
— 22 + 30	....	5.09	5.02	....
— 30 + 40	6.61	9.11	9.24	....
— 40 + 60	7.87	12.77	14.32	....
— 60 + 100	2.42	13.15	14.95	....
— 100 + 120	5.07	5.08	3.97	....
— 120	41.91	54.80	52.59	....

Crushing and Grinding

Heat Developed in Crushing.—An investigation made to determine whether the heat evolved in crushing could possibly indicate the energy used, has been made by Mr. James Cook, and reported in *Bulletin* No. 124, Institution of Mining and Metallurgy. The results are given in the accompanying Table I. The conditions of the experiment were as follows: The weight of the stamps was calculated to be within a few pounds of the round figure used, but no allowance was made for loss of weight during the three-day period of the test. The number of drops per minute was determined frequently. The average height of drop is only approximate, as it could not be determined continuously. The E.H.P. of the battery motor was read continuously and the average taken. The actual horsepower is merely the product of the estimated weight of the stamp, and the number and height of drops. The orifice of the screen used was accurately known, and various meshes were used to see whether the heat evolved varied with the mesh. The weight of water used and ore crushed were found by two methods: (*a*) gaging the water feed and the proportion of solid in the pulp sample; and (*b*) running the entire pulp into a measured tank for a certain time, and ascertaining the amount of water and solid.

The specific heat of the ore was calculated from an analysis of the ore to be 0.251, which was confirmed by a rough test in our laboratory.

The product of the number of pounds of ore crushed per minute, the specific heat, and the rise in temperature in degrees Centigrade, together with the product of the number of pounds of water per minute, its specific heat, and the rise in degrees centigrade gives the total heat units evolved per minute. This multiplied by 1390 —the number of foot pounds in one H.U. centigrade— divided by 33,000 gives the total horsepower per minute represented by this rise in temperature.

For the purposes of my original experiments the pulp was graded through I.M.M. screens as shown in the three examples given.

Of the E. H. P. supplied to the motor, it will be seen that only 76 per cent. is apparently stored in the raised stamp. The ore crushed will be seen to have been raised an average of 4.8 deg. C. while the water used was raised an average of 0.438 C.

The difference is due to the smaller portion of ore feed being at a lower temperature than the water feed.

The average temperature of the ore feed was ascertained at intervals by burying the thermometer in the ore shoot supplying the automatic feeder. This temperature was found to be practically constant.

The average temperature of the water feed was found by frequent tests.

After numerous experiments it was found that the best method of ascertaining the pulp temperature was to take large samples from the entire pulp stream into which the thermometer could be inserted and examined undisturbed.

The temperature of the building was not sufficiently above that of the pulp or feed to affect the temperature during the time of reading. The same thermometer was used to take all temperatures. This, though somewhat inconvenient, avoided any instrumental error.

The thermometer, a very sensitive one, divided into tenths of degrees centigrade, could be estimated easily to further sub-divisions by means of a magnifying glass.

Of the actual power input to the motor, practically 61 per cent. is returned as heat in the pulp. Of the energy which reached and was stored in the lifted stamp, practically 80 per cent. is returned as heat in the pulp. The 20 per cent. unaccounted for may be allocated as follows:

(*a*) Loss in friction with the guides; (*b*) loss in sound and vibration; (*c*) loss in radiated heat; and (*d*) energy with which the pulp is delivered through the screens.

At some points the screen had a higher temperature than the pulp, showing the energetic bombardment to which it was subjected by particles which partly passed or which were returned. From the table it will be observed that a difference of 3 per cent. in the heat energy was found with the two different meshes. The author is inclined to regard this as experimental error. The ore experimented on was a gold-bearing conglomerate.

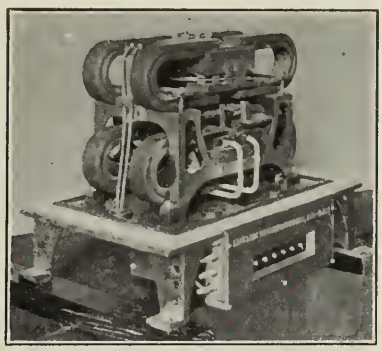
The safety-first publication of the Anaconda Copper Mining Co., known as *The Anode*, has made its appearance. It is designed to promote the safety of Anaconda men in various departments of work. We extend to *The Anode* our best wishes for a useful career.

A New Ampere-Hour Meter for Electrolytic Works and Refineries

In the electrolytic refining of metals, and in all electrolytic processes, the quantity of current used is one of the most important quantities to be measured. If measured in ampere-hours its quantity is directly convertible into pounds of copper or other metal deposited or into pounds of caustic soda and chlorine, obtained in the electrolysis of brine solutions, and affords a direct determination of the current efficiency according to Faraday's law.

It happens that in the development of the latest form of conveyor scales it became necessary to produce an ampere-hour meter of very much greater accuracy and permanence than any that had been constructed in the past and from which all delicate parts were eliminated. This resulted in the meter described below, which is also unique in the absence of any mechanical connection between the integrating element and the registering device.

The meter is of the well known mercury motor type, but the dimensions and weight of the parts have been increased many times over what has been customary in the past. The driving element, or motor chamber, is a shallow reservoir of mercury in which a copper disc revolves. Four heavy double permanent magnets with suitable pole pieces create the driving field. The torque produced is more than seven times as great as has been the usual practice. The shaft of the driving disc is extended upward and carries a large aluminium damping disc. The damping field is produced by four double magnets of the same size as the driving magnets, but with toothed pole pieces to increase the effect of the eddy currents. Above the damping disc on the same shaft is a small copper disc carrying one or more platinum points, which alternately pass just over the rim of two steel cups. Each of these cups is connected with a reservoir of mercury in such a way that a meniscus is produced which is gently swept by the platinum points. In this way a contact is effected which is available for operating the counter without drag upon the rotating shaft. The entire shaft with its driving and damping disc is floated in the mercury of the motor chamber so that there is a very slight upward pressure. The upper end of the shaft is a small polished pivot of hard steel which runs in a cupped diamond end jewel and the lower end of the shaft is simply held in place by a polished sapphire ring jewel. No oil of any kind is used on the jewels.



AMPERE-HOUR METER

The result is a meter with only one moving part the motion of which is entirely controlled by magnetic and electric forces. Not only is the driving force greatly increased, but mechanical friction is reduced to the vanishing point. This gives a speed to the meter shaft which is dependent only on the volume of current and which cannot change with the lapse of time on account of the absence of friction and mechanical wear, as well as the absence of lubrication, the condition of which would vary.

Passing now to the registering part, this is simply an electric counter of new design which constitutes a rather radical departure. There is a rocker shaft actuated by two electric counters. This rocker shaft is the only moving part except the six number wheels. There are no springs or ratchets. The rocker shaft carries a hermetically sealed glass tube containing a small quantity of mercury which oscillates with the motion of the counter, and makes and breaks a contact connected with binding posts on the outside of the meter. This auxiliary circuit is available for the connection of distant registers or recording instruments. When a recording counter is used the meter gives a graphic record of the operation of the plant for every hour of the day. In this way all shutdowns, even if of a few moments' duration, are plainly indicated, and the quantity of current delivered during any hour or any fifteen minutes of the day or night is plainly read.

The meter is equipped with suitable shunts making it available for any volume of current that is to be measured. It is manufactured by the Electric Weighing Company, 180 Thirteenth Avenue, New York City.

The Analoid Method for the Determination of Phosphorus in Steel, Iron and Slag

The standardization of analytical routine methods in iron and steel laboratories is making further progress, as is instanced by the success and further development of the "analoid method" of analysis. Invented by the English steel chemists, Messrs. C. H. & N. D. Ridsdale, and introduced in this country by the Scientific Materials Company of Pittsburgh, this method depends on the use of "analoids," that is, tablets containing just the exact quantities of the proper reagents, which have been carefully tested and apportioned to give the best result for a certain reaction in the method for which they have been specially prepared.

In our issue of December, 1914, we described the analoid method for the determination of manganese in steel, iron ore, and slag. The analoid method of determining phosphorus is perhaps of still greater value for the routine laboratory and will be described in the following article:

Preparation of Sample.—Metallic samples consisting of moderately fine drillings are suitable; however, with 0.6 to 0.8 carbon steels or higher the samples should be very fine to facilitate solution. Cast iron, should, if drilled, consist of very fine drillings, preferably pounded afterwards, or if shot samples, should be pounded to pass a 60-mesh sieve. Slags, etc., should have the same fineness.

Preparation of Solutions.—Reagent No. 1.—Nitric acid. Mix 21.5 parts nitric acid, 1.42 sp. gr., with 10 parts by volume of 3 per cent (at least) hydrogen peroxide.

Reagent No. 2.—Ammonium molybdate. Add 300 cc. of distilled water to 74 grams of molybdic acid (MoO_3) and mix well, add slowly 60 cc ammonium hydrate, 0.90 sp. gr. (or more, if not neutral to litmus), warm to not over 50° C. to aid in solution, filter and dilute to 1 liter with cold water.[1]

Reagent No. 3.—One-sixth normal sodium hydroxide (6.667 grams per liter). This solution can be prepared free from carbonate by making a saturated solution of NaOH (by alc.) in about 50 cc of distilled water. Enough NaOH must be used so that some remains undissolved together with any sodium carbonate. Allow to settle and decant clear solution into a bottle which

[1] The operator should be cautioned not to use an acid solution of molybdate, as it alters the proportioning of the reagents, volumes of liquid, temperature of precipitation, and gives erroneous results, unless proper allowance is made.

must be kept stoppered. Use 6 to 7 cc of this solution per liter of distilled water. Standardize against steel of known phosphorus content.

Reagent No. 4.—Nitric acid. Make a nitric acid solution exactly equivalent to the above sodium hydroxide solution which will be approximately correct by diluting 20 cc nitric acid, 1.42 sp. gr., to 2 liters.[2]

Procedure for Steels up to 0.3% Phosphorus.—Place the 2-gram sample in a 300-cc Erlenmeyer flask which has an approximate graduation mark at 55 cc, and add 55 cc of reagent No. 1 (nitric acid). After vigorous action has subsided, cover with small watch glass and heat at just below the boiling point until solution is complete and the brown fumes practically expelled.

Add one No. 4 analoid and heat gently for two minutes to destroy all soluble carbonaceous matter and insure complete oxidation.

Then add one No. 5 analoid, bring quickly to boil till clear, then hold at just below boiling for at least two minutes. Rinse cover of flask and dilute to 55 cc (if volume is less) with boiling water. Now precipitate the phosphorus at a temperature of 72-78° C. by adding to the boiling solution 20-25 cc of cold (10°-19° C.) neutral ammonium molybdate solution No. 2 giving a total volume of 75 to 80 cc. Shake well (vertical motion) for full two minutes and allow to settle (stoppered) for about two minutes at about 40° C. If phosphorus is low shake 5 minutes and allow to settle 10-15 minutes.[3]

A yellow precipitate, both chemically and physically perfectly uniform, granular to facilitate filtering and washing, is produced. These qualities render it especially suited to centrifugal machine treatment to produce reliable results. The precipitates so obtained may be filtered and finished by any of the customary methods, but the following method is recommended.

Filter through good quality analytical filter paper using suction, rinsing the flask with 2 per cent nitric acid, and washing till free from acid, with a solution made by dissolving one analoid No. 14 in 30 to 40 cc of hot water, cool and dilute with distilled water to one litre.[4]

The paper is removed from the funnel placed open against the inside of a 250 cc beaker, and the necessary amount of 1/6 normal sodium hydroxide solution (20-25 cc) allowed to wash the precipitate into the beaker, using an accurately graduated pipette or burette. The liquid is stirred with a glass rod until dissolved, the filter paper broken up in the solution, 100-150 cc of cold distilled water added, also 1-2 drops of phenolphtalein solution (1-100 alcohol) and the excess of sodium hydroxide titrated back with the equivalent nitric acid solution.

The difference from total NaOH used gives the number of cc. reacting with the ammonium phosphomolybdate. This multiplied by the phosphorus factor gives percentage of phosphorus (or weight if so calculated).

Procedure for Cast Iron and Pig Iron.—Sample 2.857 grams (for percentage up to 0.3 phosphorus) placed in a 250 cc beaker and dissolved in 75 cc of nitric acid solution No. 1, covered and heated gently until brown fumes are expelled. Transfer to a 100 cc flask, dilute to exactly 100 cc with cold water, shake and filter through dry filter into a dry beaker. Exactly 75 cc are transferred to a 300 cc erlenmeyer flask graduated at 75 cc. (This gives a sample equivalent to 2 grams of iron). Cover flask and heat just to the boiling point and add one analoid No. 4, simmer at least two minutes and add one analoid No. 5, heat quickly to boil until clear, then simmer at least 2 minutes. Dilute to 75 cc with boiling water and precipitate at a temperature of 68-72° C. by adding to the boiling solutions 25 cc of cold (10°-19°) neutral solution of ammonium molybdate No. 2 diluted to 40 cc with cold water, shake 5 minutes, then allow to stand as directed in procedure for steels.

The method with slight modification is adapted for analysis of high-phosphorus irons (up to 3 per cent), also to high-phosphorus slags and fertilizers.

We have described in detail the analoid method for phosphorus determination, in order to bring out in which regards it means a considerable simplification of usual methods. This matter is gone into with greater detail in a pamphlet just issued by the Scientific Materials Company of Pittsburgh, Pa.

[2] Although solutions No. 3 and No. 4 are for use in the "acid-alkali" method, any of the usual methods may be used after the precipitation of the yellow precipitate.

[3] If the solution is allowed to stand in a warm place much longer than the prescribed time, arseno and silico molybdates may be more or less precipitated and give a high result; but if at ordinary temperature, 18-23° C., this is usually avoided.

[4] This removes the acidity without dissolving the yellow precipitate whereas water if used would dissolve it.

Sentinel "Pyrometers" and Paste and Their Uses

A new method for measuring temperatures, similar in principle to Seger cones, has been developed by the Carl Nehls Alloy Company, of Detroit, Mich. Different kinds of metallic salts have been made up of such chemical compositions as to have definite different melting points throughout the temperature range between 425

FIG. 1—SENTINEL PYROMETERS AND PASTE AS MADE AND USED

and 2425 deg. Fahr. (218 to 1329 deg. Cent.). They may be used, like Seger cones, for measuring temperatures, and are also very useful for checking pyrometers. For the latter purpose a cylinder is placed at the end of the thermocouple and when it melts the pyrometer should read the same as the temperature marked on the "Sentinel."

One way of using these metallic salts compositions is to cast them into solid cylinders, 7/16 in. in diameter and 3/14 in. long, as shown by those standing on one end in Fig. 1. Each one is wrapped in a paper on which is printed its correct melting temperature in degrees Centigrade. These are shown by the samples lying down. For all temperatures below 932 deg. Fahr. these "sentinel pyrometers" can be used in an air-tight glass tube such as is shown in the center. The salts can then be used over and over again. By using the small porcelain saucer shown, the salts do not run to waste and litter up the place where they are used. This also enables them to be used several times, as the salt will melt each time the temperature raises above the one marked on the cylinder and it will become solid again the moment the temperature falls below this degree.

These salts are also made up in the form of a paste.

Enough to make several hundred determinations is packed in the tins shown. Pastes with various melting temperatures can be daubed along a steel bar, as shown in the front of Fig. 1, and inserted into ovens, furnaces, retorts, flues, gas mains, steam pipes, etc., to find the temperature at which they are operating. The salts that melt down and those that remain solid will indicate the temperature which would be between the two. By using a long bar one can determine whether the temperature is uniform in the front and back, top and bottom, or corners of a furnace, oven, kiln, etc.

This is an easy method for obtaining the exact temperature of tools heated in a forge fire. A paste is

FIG. 2—"SENTINEL PYROMETER" USED IN TUBE IN POT FURNACE

selected that represents the correct hardening temperature for the tool. This "sentinel paste" is daubed on the tool and when it is heated to this temperature the salt will melt and the tool can be taken out of the fire and quenched. It will make it easier if the tool is surrounded by a piece of sheet steel or is inserted in gas pipe as that keeps the paste from coming in contact with the fuel.

Another handy way of using the "sentinel" cylinders is to plug one end of a tube or pipe and drop a sentinel cylinder into the tube. A small rod can then be lowered into the tube and made to rest on the salt. When the salt melts down the rod will lower and thus indicate that the melting temperature of the salt has been reached. This is very useful for finding the temperature of molten metal, salt bath furnaces, etc. Fig. 2 illustrates this method.

A Special Paper for Recording Instruments, Drawings and Similar Purposes

A chemically surfaced paper of high merit has recently been put on the market by the Non-Carbon Paper Company, 14 Federal Street, Boston, Mass., which should be of considerable interest to manufacturers and users of recording and registering instruments. Several years of experimenting and a large expenditure have been necessary to produce a product of this kind.

To produce a paper which would be satisfactory as a chart for the various kinds of instruments, some requiring a sensitive surface and some a hard one, was the problem to be solved. Further, a surface had to be created upon which printing could be done satisfactorily for the making of charts, graphs, tapes and other devices. Then the sensitiveness had to be satisfactory within the wide range from the recording instruments requiring a firm surface to the more sensitive finish required by instruments of a delicate nature. These problems have all been worked out and a high-grade paper manufactured to fit any and all of these needs.

Another valuable feature of this paper is its utility in the engineering department for the production of sketches and drawings. A still wider field is opened up by the fact that this paper is especially valuable in the second-sheet field, where records of correspondence may be made through its use without the aid of carbon paper. This paper is adaptable to auto trucks and vehicle recorders, speedometers, electric and water meters, steam gauges and water-pressure instruments, recording thermometers, pyrometers, hightenographs, magnetographs, time locks and time registers, movement indicators, fatigue testing instruments, pulsation recording and respiration registering devices, pneumatic orbits or movements of scientific machines. Copies of records can be obtained by inserting sheets corresponding with the form print.

Bronze Castings as a Substitute for Steel Parts

Machine parts of steel are inexpensive as far as the cost of the material is concerned, but if the cost of machining, grinding, hardening, finishing, etc., is considered, they may become so expensive that their equal weight in bronze or silver, or even gold, will be worth less. Often a preferable machine construction has to be abandoned for the reason that the making of one or more of the necessary parts cost too much if same have to be machined, especially in quantity work.

Where strength, toughness, resilience, wearing quality and durability could be neglected, the products of the white-metal die-casting industry overcame the obstacle caused by the high machining cost, as its products leave the moulds smooth, true and accurate, and therefore need little finishing work. However, the good qualities of steel, either soft or hard, can be reached and even greatly excelled by brass (copper with zinc), bronze (copper with tin) and other modern copper-base metal compositions, but against their use stands their high material cost unless the same can be balanced by the saving of finishing labor, as is often the case.

If, however, it becomes possible to produce also copper-base metal composition die castings smooth and accurate, then the saving of finishing expenses in many instances would excel the higher cost of the material, and at the same time there would be an opportunity of substituting a superior material for the steel.

The McGill Metal Company of Valparaiso, Indiana, has entered this new field of industry, that is, of casting copper-base metal compositions in permanent steel moulds or dies. After systematic experimental work and after furnishing bronze-die castings for two years to a limited number of customers for thorough tests, this company saw such an encouraging success that it is now erecting a new permanent foundry and die shop with a modern equipment for making bronze castings in permanent steel moulds.

Among the many difficulties which the experimental plant had to overcome were: To work out bronze compositions of perfect equilibrium at all temperatures,

and of sufficient strength, even at a high temperature to withstand all strains caused by its own shrinkage around the steel cores in the dies. Even the best brasses and bronzes used commercially heretofore fell short in these requirements, likewise no make of steel found on the market did meet the requirement of withstanding the attack of molten metals at temperatures of from 2200 to 2400 deg. F., as is needed with the mould material. Therefore, special steel alloys had to be developed to suit the purpose.

One of the fields in which the McGill metal castings worked remarkably successful was the quantity production, at a reasonable price, of strong, tough, hard and durable bevel-gears with correct teeth. As is well known, the cost of cutting correct bevel gear teeth is prohibitive in regular quantity manufactured, however, if the cutting of correct teeth need to be done for once only in a die, and if in this die hard and tough bronze can be cast successfully the production of strong and correct bevel-gears can be accomplished without needing any mechanical work at all on the teeth. And if the material is superior to correctly case-hardened or tempered steel in every respect, then also the manufacturer avoids the uncertainty and risks of the heat treatment of steel. These aims are accomplished by the McGill metal casting process.

The McGill metal castings are finely granular or fibrous and homogeneous, have a great cohesion and flowing power even with their hard varieties; they can be forged red hot or cold, and can be machined with ease. Vibrations, shocks, strains as well as heat if within reasonable limits will not influence their fine and uniform grain, nor their strength, hardness, toughness and springiness as continuous exposures for two years have proven. Those qualities can be regulated by varying the compositions. Not being attained by secondary treatments these qualities being innate will last and not change in time or by use.

The castings take a high polish on account of the fine close grain, and will practically show almost no wear even when run without lubricator, under great load, and with great speed. Therefore, they are ideal where subject to rolling, sliding or pounding, as is the case with gears, cams, clutches, couplings, sliding (reciprocating or rotating) valves, poppet valves, bearings and bushings.

The color of the metal is a golden yellow. It contains about 90 per cent copper and withstands well the action of acids, alkalies and salts. The users of the material will not be troubled with rusting and corroding, nor with pitting. Against the latter the hardness and closeness of its grain is an additional protection.

Physical tests with the material gave the following results: Tensile strength, 75,000 to 85,000 lb. per square inch, with an elastic limit of 30,000 to 40,000 lb., and elongation of 18 to 23 per cent on a 2-in. test length, and a reduction of area of 17 to 24 per cent.

Portable Welding Outfit for Metallurgical Works

The rapid progress made by autogenous or fusion welding throughout the metal industry is an indication of the numerous advantages possessed by the process. The object of this method of welding is to bring the metal, at the point of treatment, to a liquid state so that the parts to be united will fuse and flow together in a practically homogeneous piece. The heat employed for the purpose may be generated either by electricity or by means of thermit or by burning a combustible gas with oxygen.

Acetylene gas is highly suitable for the purpose, the temperature of the oxy-acetylene flame being about 6300 deg. Fahr. The decomposition of acetylene (C_2H_2) when burned with oxygen presents some features valuable in welding. The high temperature of the oxy-acetylene flame, caused by the combustion of carbon, is above the temperature of dissociation of steam, so that water is not formed as a product in the flame. The hydrogen from the acetylene does not enter into combination with oxygen until after it has left the high-temperature zone of the welding flame. This produces a zone of hydrogen, more or less free, surrounding the welding flame, giving a reducing atmosphere and preventing oxidation of the metal.

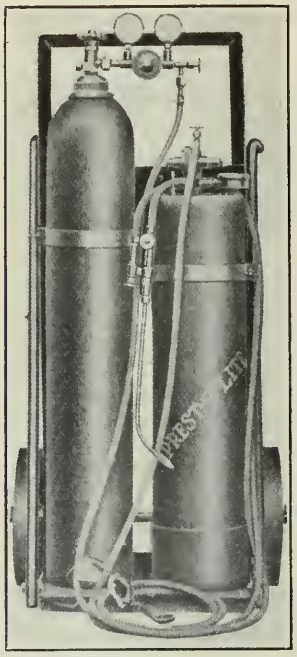


FIG. 1—PORTABLE WELDING OUTFIT

The application of oxy-acetylene welding is a comparatively simple matter in ordinary work, and men are readily trained to use it efficiently. The process, therefore, is one that can be profitably applied in repairing broken machinery in concentrating and cyanide mills, smelters and metallurgical works generally. At isolated plants it is especially valuable in reducing losses incident to broken machines, and avoiding delays due to getting new parts or sending broken ones out for repair.

The process has been made particularly available for this kind of work through the portable Prest-O-Welder outfit, which has been placed on the market by the Prest-O-Lite Company, Inc., of Indianapolis, Ind. As shown in Fig. 1, it consists of two cylinders, with pressure gages, hose, blow-pipe and tips, mounted on a truck. One of the tanks contains compressed oxygen and the other acetylene prepared according to the Prest-O-Lite process. The oxygen cylinder can be recharged at various places in the country, and the Prest-O-Lite cylinder is exchangeable through the company's numerous service stations which are widely distributed.

The entire outfit weighs less than 300 lb., and being portable and compact, it affords the greatest convenience and efficiency. In this respect it is superior to stationary acetylene generating apparatus, to which repair work must be taken, often at added expense or inconvenience. The purity of Prest-O-Lite gas is an added advantage over that generated from carbide and water, for the impurities in the latter affect the weld and can be removed only through the use of expensive apparatus. Further, Prest-O-Lite will not freeze in cold weather and is always ready for use. The entire apparatus is simple, durable, convenient, safe and under perfect control. Considering these features, it should find a broad field of usefulness in mills and smelters.

The Iron and Steel Market

Steel mills at the end of February were operating at between 55 and 60 per cent of capacity. Operations in January averaged fully 45 per cent of capacity and the average for the first two months of the year is fully 50 per cent, against about 35 per cent in November and December.

The recovery in demand is real, but it is halting and

hesitating. The mills have maintained their increased rate of operation only by making up their rolling schedules at short intervals, practically from day to day, and any decrease in the current demand would at once be followed by decreased operations.

There has been little if any increase in the demand for steel for important permanent investment. The railroads have taken a very small part in the buying, and there is very little in the way of large structural enterprises. It would appear that what has occurred is simply that towards the close of the old year jobbers and manufacturing consumers drew upon stocks, causing mill production and shipments to fall below the actual rate of ultimate consumption, and that since the first of the year this factor has disappeared, while there has been a slight increase in consumption.

The hopes of the steel trade now rest upon an increase in consumption due to the near approach of spring, permitting an expansion in outdoor work and due also to the better financial and economic conditions which should lead to the investment of capital in extensions and new enterprises.

Export trade holds out no great hopes, as there were declines in November and December from the record of October. Exports of iron and steel, including scrap, pig iron, rolled iron and steel, cast and wrought pipe, wire, nails, etc., have been as follows, in gross tons:

January	118,770	July	114,790
February	121,206	August	86,599
March	159,998	September	96,476
April	161,952	October	147,293
May	139,107	November	140,731
June	144,003	December	117,655

Year—1,548,680

For about a year and a half the steel industry has been operating at all times at considerably less than its capacity and while statements are made in the trade with more or less confidence that this or that plant, or the industry as a whole, is operating at a certain percentage of capacity, it is doubtful whether the real capacity is definitely known. It is possible that under the most favorable circumstances an output could be attained much beyond the rated capacity, and it is equally possible that upon short notice the industry could not reach a rate of operating even at nominal capacity, there being in the chain so many links of uncertain strength. It might be therefore that with a further and only moderate increase in demand the mills would begin falling behind in deliveries of some products. Such an event would undoubtedly arouse overnight a demand for hundreds of thousands of tons of steel, as jobbers and manufacturing consumers are operating with extremely light stocks, being able as a rule to secure shipment from mill a few days after the filing of specifications, and any question raised as to the promptness of shipment would at once induce these buyers to attempt to add to their stocks. Despite the very conservative views entertained on all hands as to the future of the market in the next few months there is a distinct possibility of a period of decided activity marketwise with consequent sharply rising prices.

Pig Iron

The pig-iron markets throughout the country have been showing remarkable steadiness in prices and a very decided lack of activity at the same time. The buying movement of late in the old year seems to have covered consumers comfortably, as to their present rate of operation, as there are practically no complaints of consumers not taking deliveries as contracted for, yet the total production continues light, as light as for several years. There has been a sharp increase in pig-iron production by the steel interests, but none by the merchant furnaces. As many of the existing contracts are for the quarter only, an increase in buying is expected in March. Quotations show scarcely any change from those of one month or two months ago, and are as follows: No. 2 foundry, Birmingham, $9.50; delivered Philadelphia, $14.50; f.o.b. furnace, Buffalo, $13; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13; at valley furnaces (95 cents higher delivered Pittsburgh) Bessemer, $13.60; basic, $12.50; No. 2 foundry, $12.75 to $13.25; malleable, $12.75; gray forge, $12.50 to $12.75. Ferromanganese on contracts is nominal at $68, Baltimore, there being question about delivery on account of the embargo. Small prompt lots have been commanding $85 to $100, a decided advance in the month.

Steel

It develops that one or two of the Youngstown mills did not secure as much billet and sheet bar business as desired, and they have not participated in the advances made by Pittsburgh mills, the result being that quotations at Youngstown are substantially as low as a couple of months ago, while the Pittsburgh mills are forced to be content with their contract tonnage and are not naming competitive prices. We quote billets at $18.25 to $18.50 and sheet bars at $18.50 to $19, f.o.b. maker's mill, Youngstown, and $1 higher delivered Pittsburgh. Rods are $25 to $26, Pittsburgh.

Finished Steel

In December the regular market for bars, plates and shapes was 1.05c. for specifications to be filled in December for early shipment, 1.10c. for first quarter contracts and 1.15c. for second quarter. At the end of December the 1.05c. price was withdrawn. Early in February former prices for forward deliveries were withdrawn, mills then quoting 1.10c. for February specification, 1.15c. for March and 1.20c. for second quarter, in substance leaving it to the calendar to effect an advance, and the question is whether the beginning of March will witness a disappearance of the 1.10c. price. At the same time the National Tube Company began quoting steel pipe at a one-point advance for specifications to be filed in April, and a two-point advance for May and June. This was followed on February 11 by the issuance of a new list with a straight advance of one point on black steel pipe 6-inch and under, and an advance of three points on galvanized steel pipe ¾ to 6-inch, this extra advance on galvanized pipe being due to the record high price and extreme scarcity of spelter. Effective February 12 wire products were advanced $1 a ton. The continued advances in spelter forced higher and higher prices for galvanized sheets and in the last week in February all the mills that were quoting at all advanced to 3.40c. for 28 gage, even then accepting orders only for immediate specification and prompt shipment. Nominally the advance due to the advance of spelter to nine cents or higher is $13 a net ton, but practically it is $16, as while the openly quoted market had not gone below 2.75c. there were some contracts made in December at 2.60c.

Current quotations are as follows for ordinary deliveries, quotations being f.o.b. Pittsburgh unless otherwise noted.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.10 to 1.15c.

Shapes, 1.10 to 1.15c.

Steel bars and bands, 1.10 to 1.15c.; base, hoops, 1.25 to 1.30c.

Refined iron bars, 1.15c., Pittsburgh; common iron bars, 1.12½c., Philadlphia; 1.05c., Chicago.

Sheets, blue annealed, 10 gage, 1.30c.; black, 28 gage, 1.80 to 1.90c.; galvanized, 28 gage, 3.40c.; painted cor-

rugated, 28 gage, 2.00c.; galvanized corrugated, 28 gage, 3.45c.

Tin plate, nominal price $3.20 for 100-pound cokes; large lots at $3.10 or possibly less.

Steel pipe, ¾ to 3-in., 80 per cent off list.

Steel boiler tubes, 3 1/3 to 4½-in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Cold rolled shafting, 68 per cent off list.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Chain, ⅜-in. proof coil, 3.00c.

Montana Section of American Institute of Mining Engineers

The annual meeting of the Montana Section of the American Institute of Mining Engineers was held in Butte on the evening of Feb. 5. More than fifty members and guests enjoyed a dinner at the Silver Bow Club preceding the business and technical session. The following officers were elected for the ensuing year:

Chairman, F. M. Smith, manager East Helena plant of the American Smelting & Refining Company.

Vice-chairman, J. L. Bruce, manager of the Butte & Superior Copper Company.

Secretary-treasurer, D. C. Bard, professor of geology, Montana State School of Mines.

Executive committee, Frederick Laist, chief metallurgist Anaconda Copper Mining Company, and W. C. Siderfin, manager of the W. A. Clark interests in Montana.

The secretary's report shows an active membership in the state of 160. Arrangements were considered for having the Montana Section represented at the San Francisco meeting of the Institute next September.

Two technical papers were presented and discussed. One on the concentractor of the Timber Butte Milling Company, by Theodore Simons, (see Synopsis in this issue), the other on "The Boulder Batholith of Montana," by Paul Billingsley. The Montana Section of the Institute meets twice a year. It is growing in membership, and its usefulness is being increased as interest in the organization grows among mining men.

Personal

Dr. Lucien I. Blake, of Boston, is expected in Denver March 1. While there he will deliver a series of ten lectures on Cosmic Physics before the Teknik Club, and an additional course on Molecular Physics at the Colorado School of Mines.

The Colorado Iron Works Company has opened a down-town office in Denver for the accommodation of its friends and customers who may find it inconvenient to visit the main office at the works. The new office in the Ideal Building, Seventeenth and Champa Streets, is in charge of Mr. Hugh B. Lowden, secretary of the company. Mr. Randall P. Akins, sales manager, will also make this office his headquarters when in the city.

Mr. C. A. Filteau has sailed from New York, via Panama, for Carabaya, Puno, Peru, where he will manage the affairs of the Inca Mining & Development Co.

Mr. Robert A. Marr is metallurgist for the Platinum Mining & Milling Co., at Holmes, Wyo.

Mr. Arthur G. McKee announces that **Mr. Robert E. Baker** and **Mr. Donald D. Herr,** his business associates during a number of years past, have joined him in the incorporation of the engineering and contracting firm of Arthur G. McKee & Co.

Mr. Philip S. Morse, who has been manager of the mines, mills and smelting works of the Sulphide Corporation in New South Wales, has resigned his position and returned to the United States.

Messrs. Jacques Negru, Paul S. Nice and **Thomas Charlton,** all of Denver, Colo., have associated themselves as the Chemical and Engineering Institute. A general consulting business in chemical engineering will be conducted with offices in the Central Savings Bank Building.

Mr. Edgar L. Newhouse has been chosen first vice-president of the American Smelting & Refining Co., succeeding the late Barton Sewell. Messrs. Edward Brush and S. W. Eccles also have been advanced in the line of vice-presidents.

Prof. **Robert H. Richards** has been awarded the gold medal of the Mining and Metallurgical Society of America, in recognition of his services in the advancement of the art of ore dressing. The formal presentation will not take place until March.

Mr. W. G. Swart, mining and metallurgical engineer of Denver, Colo., with offices at the Foster Building, has joined the Hardinge Conical Mill Company in the capacity of consulting engineer in the West.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Electroplating Alloys

98,110, Dec. 21, 1869, Samuel Rust, Jr., of Cincinnati, Ohio.

Relates to electrodepositing brass and other alloys upon iron, zinc and other metals, and an apparatus therefore, which consists of a large tank having a steam-coil on the bottom. The solution is made as follows: First solution, 1¼ lb. of cyanide of potassium, 1⅜ lb. of carbonate of ammonia, 1 gal. of distilled water; second solution, ½ ounce of bisulphide of carbon, 4 ounces of cyanide of potassium, 1 pint of distilled water, shake until dissolved. To 1 gal. of the first solution add ½ ounce of the second solution, mix and allow to stand for twenty-four hours, or longer. Before using decant as much as possible of the clear solution and filter the remainder from any sediment. Fill the tank and a porous cup with the clear solution, in the porous cup place a brass or copper cathode, and a sheet of brass for an anode in the outer tank; pass a current until the required amount of brass has been dissolved, then remove the porous cup and cathode. The solution is now ready for use. The temperature should be about 180 deg. Fahr.

103,947, June 7, 1870, William Henry Walenn, of London, England.

Relates to electrodepositing brass and describes several electrolytes, one of which is as follows: One part by weight of crystallized sulphate of zinc, two parts by weight of crystallized sulphate of copper, are dissolved in the least possible water. Sufficient strong ammonia water is added to precipitate and then fully redissolve the oxides. The purple tint of this solution is completely removed by a standard solution of cyanide of potassium, left to stand for a day or two, and may then be worked with from one to three battery cells, using heat if a brass anode be employed. The patent should be consulted for further details.

155,700, Oct. 6, 1874, Edmond Boy, of New York, N. Y.

Relates to preparing an electrolyte for depositing an alloy to be used for ornamenting articles of copper, iron, etc. The solution is prepared as follows: To about 200 parts by weight of hot water add twenty parts of powdered arsenic, (probably uses one of the oxides of arsenic); after solution, add twenty parts of cyanide of

potassium, and allow the liquid to remain until it is clear. Grind together one part of sulphate of copper, one part of sulphate of zinc and four parts of carbonate of soda, dissolve in water and mix with the above solution, stir thoroughly and allow to stand. A small quantity of cyanide of potassium may be required to perfect the solution. For use the solution is kept at a boiling heat, the article to be plated suspended therein as cathode and platinum or other metal used as anode. A strong current is required. The deposit obtained is of a lustrous bronze color and highly ornamental.

223,210, Dec. 30, 1879, William Frishmuth and Herman B. Van Tronk, of Philadelphia, Pa.

Relates to electrodepositing an alloy of nickel and aluminium, from an electrolyte containing 6 ounces of nickel chloride, 2 ounces of a mixture made of two parts of chloride of aluminium to one part of chloride of sodium, the proportion of nickel salt and mixed aluminium-sodium salts being dissolved in 1 gal. of water. A strong current is passed through the solution from a nickel anode to a carbon cathode, until the solution is in proper condition for plating, when the carbon is removed. The solution is now ready for use. In place of nickel chloride there may be used nickel sulphate or nickel nitrate.

228,900, June 15, 1880, James S. Howard, of Springfield, Mass., assignor to James M. Abbott, of Waterbury, Conn.

Relates to an improvement in solutions for electroplating with an alloy of which aluminium is the base. One pound of a mixture of one part cryolite, one part chloride of magnesium and one part chloride of manganese, combined in the form of a powder is added to 1 gal. of water and boiled until thoroughly dissolved. The granulated alloy anode is placed either in an open network or may be placed on the bottom of the lead-lined tank, in which latter case the current is connected to the lead lining.

231,064, Aug. 10, 1880, George Linsenmayer, of Philadelphia, Pa.

Relates to electrodepositing an alloy of aluminium and gold from a solution prepared as follows: First solution: To 10 liters of distilled water add 7 ounces of phosphate of soda, 1½ ounce of sal-ammoniac and 1 ounce of magnesia. Second solution: To 5 liters of distilled water, add 2 ounces of bicarbonate of soda, ½ ounce of muriate of soda, ½ ounce of flowers of sulphur and 1 dwt. of acetic acid. Third solution: To 8 liters of distilled water, add 10 ounces of cyanide of potassium and 15 dwt. of spirits of wine. When all the substances are dissolved pour the three solutions together and boil for half an hour, cool and add 2 ounces of burnt alum dissolved in 1 liter of water, 1 ounce of aluminium and 1 ounce of gold, the latter previously dissolved in nitro-muriatic acid and 4 ounces of cyanide of potassium with 1 ounce of aqua-ammonia. Boil again for half an hour, then filter while hot. The solution is now ready for use; it should be used at a temperature of 180 deg. Fahr. to 200 deg. Fahr.

248,554, Oct. 18, 1881, Milton H. Campbell, of New York, N. Y., assignor to himself and Norvin Greene, of same place.

Relates to electroplating silver or silver-plated ware for the purpose of protecting their surfaces from corrosion or tarnishing. The articles are plated with a homogeneous alloy consisting of from twenty-five to thirty-six parts of platinum and seventy-five to sixty-four parts of silver. With less than ten parts of platinum the alloy is not capable of resisting the stronger corrosive agents, such as nitric acid and the sulphides. In making the plating solution, the alloy is converted into a compound chloride of platinum and silver, by dissolving in nitric or nitro-muriatic acid, heated to boiling. This solution is diluted with about four times its volume of water and then a hot saturated solution of chloride of ammonia is added to precipitate the chlorides. About 1 ounce of the compound chloride is dissolved in 1 gal. of water, with a sufficient quantity of cyanide of potassium added thereto to afford a clear solution, which is used as the electrolyte. In electroplating, an anode of the alloy of platinum and silver is used. (See also his later patent No. 253,159.)

253,159, Jan. 31, 1882, Milton H. Campbell, of New York, N. Y., assignor of one-half to Norvin Greene, of same place.

Relates to electroplating silver or silver-plated ware for the purpose of protecting their surfaces from tarnishing while in the wholesale and retail stock and contains a reference to his earlier patent, No. 248,554. The deposit of alloy of platinum and silver described therein should weigh about 6 grains per square foot of electroplated surface. Such a thin deposit will not withstand wear; a heavy deposit is recommended for permanent protection. The current used to effect the deposit should not be too strong or silver will deposit almost exclusively. A current that will deposit 6 grains of alloy per square foot in five minutes is considered about right, although a still feebler current is preferred.

Book Reviews

The Fixation of Atmospheric Nitrogen. By **Joseph Knox.** 5 by 7½ in., 112 pages; price, $0.75. New York: D. Van Nostrand Company.

The author is lecturer on inorganic chemistry in the University of Aberdeen. The theoretical principles are clearly explained, while the technical side is briefly sketched, being principally condensed from T. E. Norton's "Utilization of Atmospheric Nitrogen"—with acknowledgment. Those unacquainted with the subject will find it a good book to begin with.

Cyanamid. Its Manufacture, Chemistry and Uses. By **Edward J. Pranke,** B.Sc. Octavo (14 x 22 cm.), 112 pages; price $1.25. Chemical Publishing Company, Easton, Pa. Williams & Norgate, London.

The topics treated are: discovery and manufacture, properties, analysis, storage, fire and water hazard, decomposition in the soil, toxicity, fertilizing properties. The book is clearly and carefully written, and will be useful to anyone studying the properties and uses of cyanamid; its manufacture is treated altogether too briefly, apparently intentionally so.

Modern Technical Drawing. By **George Ellis.** Duodecimo (13 x 20 cm.), viii + 200 pages; price $2 net. London: B. T. Batsford. New York: D. Van Nostrand Co.

This strikes us as a practical and well-written book, well adapted to explain and illustrate the making of working drawings. The directions for lettering are plain and sensible, without any of the fancy half-illegible letters which so often disfigure drawings. A few directions as to making blue-prints would be a desirable addition. The chief chapters are upon othographic projection, isometric projection, oblique projection, perspective, free hand, practical geometry, lettering, and workshop drawings.

Die Theorie der Strahlung und der Quanten. Transactions of the Solvay Symposium, Oct. 30 to Nov. 3, 1911; with an appendix on the Development of the Quanten theory to August, 1913. Edited in German by A. Eucken. (Abhandlung Nr. 7 der Deutschen Bunsen-Gesellschaft für angewandte physikalische Chemie.) 16 x 24 cm, 405 pages, 24 illustrations; price 15.60 marks. Halle a. S: Wilhelm Knapp.

This is a collection of papers read at the Solvay

Congress by H. A. Lorentz, J. H. Jeans, E. Warburg, H. Rubens, M. Planck, M. Knudsen, Jean Perrin, W. Nernst, Kamerlingh Onnes, A. Sommerfeld, P. Langevin and A. Einstein, with appendix by A. Eucken. Among those taking part in the discussions may be mentioned Poincaré, Madame Curiè, Lord Rayleigh, Wien, Rutherford, Hasenöhrl and Lindemann, besides the authors of papers. There is some wonderful information and speculation in the volume, which make it highly instructive and stimulating to the student of advanced physics and chemistry. It is perhaps the best source of precise information about the Quanten hypothesis, which here appears as about half established and half in conflict with orthodox thermodynamics.

A Textbook of Chemistry. By **William A. Noyes.** Duodecimo (12 x 20 cm.), xv + 602 pages, 110 illustrations; price $2.25. New York: Henry Holt & Company.

Professor Noyes and his numerous assistants have worked three years on this book, and as it stands it embodies the experience of a whole chemical laboratory in the presentation of chemical facts and theory. In one way the book is commonplace, in that it presents the facts clearly but without enthusiasm, its tendency being rather to over-burden and discourage the student by too numerous and too detailed facts, without much appeal to his imagination. On the other hand, as a saving grace, there are frequent appeals to the student not to learn mechanically, but to analyze statements into their constituent parts, and reason out complex results from simple fundamentals.

Teachers who can incite enthusiasm for the subject by taking the students in hand and teaching the facts and theories in this analytical manner, will be able to use this text-book as a useful vade mecum in their class work.

Incidentally, we would register a warning against the tendency of text-books of chemistry to degenerate into small chemical encyclopedias. Dozens of good and useful chemical text-books have in successive editions suffered from elephantosis, with their usefulness as text-books varying in inverse proportion to their size. Even if the student learns from such monstrosities mere chemical facts (which is not true beyond peradventure), yet he probably learns from them less chemistry.

Filters and Filter Presses for the Separation of Liquids and Solids. From the German of **F. A. Bühler,** with additional matter relating to The Theory of Filtration and Filtration in Sugar Factories and Refineries, by **John Joseph Eastick.** 184 pages, 327 illus. Price, $4.80. London: Norman Rodger.

This is chiefly a descriptive book. The first part deals with filter construction. Filters with a loose filtering layer (open filters; closed filters; apparatus for reduction of iron from water; water softeners; the spirit filter), are first considered (thirty-five pages). A discussion (fifty pages) follows of filters with woven or flted filtering mediums (open filters; continuous action drainer-filter; bag or frame filters; Ehrenstein's pressure chamber filter; the filter press, its construction and different types). Brief chapters follow on filters with rigid filtering layer on separating apparatus without filtering layer, and presses for the separation of liquids and solids.

So far the book is essentially a translation of Bühler's German book and as such it should be welcome to American readers, though its usefulness is limited by the fact that almost exclusively German practice is considered. To repair this defect somewhat, the English translator has added some further chapters. First, a brief discussion on the theory of filtrations and a useful chapter of twenty-six pages on filtration in the sugar industry. In the latter a description is given of the Kelly filter press and the Sweetland filter press. The use of kieselguhr for filtering is dealt with at some length. Suction filters which have assumed such great importance in cyanide work in this country, are passed over with the remark that vacuum filters are not often used in sugar-house work because to filter rapidly the liquors must be hot, and when a high vacuum is applied, hot liquids begin to boil and thus destroy the vacuum. Descriptions of a few types of centrifuges are given, as they are essentially rotating pressure-filters.

For the list of German patents given in the original book of Bühler, a list of British patents covering the same subjects has been substituted (twelve pages), while in the section covering "Specifications of sundry filter press patents" (twenty-two pages) the text of the British specification has been followed where available. Otherwise the German version is reproduced in full.

The Silicates in Chemistry and Commerce. By Dr. **W. Asch** and Dr. **D. Asch.** Translated by **Alfred B. Searle,** with critical notes and additions. Large octavo (15 by 25 cm), xx+, 456 pages. Price, $6. New York. D. Van Nostrand Company.

The bulk of this treatise is based on a monograph prepared by the Doctors Asch upon the hexite-pentite theory of silicates. The basis of this is the assumption that six atoms of silicon with six atoms of oxygen form a closed ring having twelve free valences, or that six atoms of aluminium with six atoms of oxygen form a closed ring having six free valences. These are called "silicon hexite" and "aluminium hexite" respectively. Similarly, five atoms of each form, with oxygen, closed rings having ten or five free valences respectively, and called "silicon pentite" and "aluminium pentite" radicals.

From this starting point the authors attempt to explain the constitution and chemical characteristics of all silicates and alumino-silicates, along with many of their industrially useful physical properties. The attempt is most ambitious, painstaking and interesting, and gives many new points of view for the consideration of such subjects as the constitution and properties of clays, ultramarines, Portland cement, slags, porcelain cements, glass, enamels, porcelain.

The authors extend the principle to the study of complex salts of molybdenum and tungsten, and even devote a chapter to the consideration of the theory "as a general theory of chemical compounds," in which it is used to explain water of crystallization, metal ammonias, carbon compounds, and the constitution of the chemical atoms.

In the last section of the book the theory becomes the stereo-hexite-pentite theory, being considered stereochemically in order to combine it with the modern theory of the structure of crystals, and to explain polymorphism and isomorphism.

The work concludes with the tabulation of several hundred analyses of silicates and their comparison with the requirements of the theory.

It is difficult to characterize this tremendous piece of work in a few words. It is a mine of information on many unusual topics; it will be very interesting to the chemist and physicist, as possibly containing the seeds of many new discoveries and advances; and yet it is not convincing or altogether satisfactory. One feels that the authors have made a splendid presentation of their case, and yet leave this impression on the mind of their readers: "not proven."

Metallurgical and Chemical Engineering

A Consolidation of Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII — New York, April, 1915 — No. 4

PUBLISHED MONTHLY BY THE
McGraw Publishing Company, Inc.
James H. McGraw, President.
A. E. Clifford, Secretary.
John T. DeMott, Treasurer.
239 West 39th Street, New York.
Telephone Call, 4700 Bryant.
Cable Address, Metchem, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Colo.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.
J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; *for all other countries,* $2.50. (*European exchange,* 10 *shillings,* 10 *marks,* 12.50 *francs.*)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

New York, April, 1915

EDITORIAL:
Why Play to the Galleries? 199
A Spectacular Spelter Market 199
Illuminating Pig Iron Statistics 200
A Suggestion in Patent Reform 200
High-Grade Ore 201
READERS' VIEWS AND COMMENTS:
The Radium Situation. By Stewart J. Lloyd and Warren F. Bleecker 202
Carbon Bricks for Blast Furnaces. By Joh Harden 202
Comparisons of Electric Resistivities at High Temperatures. By Carl Hering 202
Chemical Engineering versus Engineering Chemistry. By Charles S. Palmer 203
Separation of White Metal and Gunmetal Borings. By R. H. Walton and Gregory T. Bailey 204
Tube-Milling in All-Slime Cyanide Practice. By W. J. Pentland 204
Grinding Ore for Cyanidation: A Suggested Modification for All Slime Practice. By W. J. Pentland 205
The Danger of Throwing Inventions Open to the Public. By Henry D. Hibbard 206
The Western Metallurgical Field 206
The Non-Ferrous Metal Market 208
The Iron and Steel Market 208
Conditions in Mexico 209
Atlantic City Meeting of the American Electrochemical Society 210
New Orleans Meeting of the American Chemical Society 210
The Electrochemical Production of Organic Compounds. By C. G. Fink, F. A. Lidbury, H. Hibbert, and G. S. Forbes .. 211
The Fixation of Atmospheric Nitrogen. By W. S. Landis 213
The Formation and Decomposition of Sulphates During Roasting. By Boyd Dudley, Jr 221
Metallurgical Smoke 226
Filling the Blast Furnace. By J. E. Johnson, Jr 227
Hydrometallurgical Treatment of Michigan Copper Tailings. By R. D. Leisk 233
Safety-First, First-Aid and Welfare Work of the Colorado Fuel and Iron Company 234
The Determination of Chromium and Vanadium in Steel. By C. H. Rich and G. C. Whittam 238
Removal of Carbon Bisulphide from Coal-Gas 240
Standard Boiler Specifications 240
Fixation of Atmospheric Nitrogen. By L. L. Summers and F. S. Washburn 241
Chemical Reactions at Low Pressures. By I. Langmuir 244
The Proposed British Dyestuff Industry. By O. N. Witt 246
Recent Chemical and Metallurgical Patents 249
Synopsis of Recent Chemical and Metallurgical Literature 251
Metallurgical and Chemical Engineering in Great Britain 254
Copper Cyanide Plating Solutions. By Max C. Weber 255
Refractories of the Rocky Mountain Region and Some of Their Products. By J. C. Bailar 257
Regulation of Electrotyping Solutions 258
The Tapolog, a New Multiple-Record Pyrometer Recorder 260
A Flourishing German Smoke Abatement Society. By John B. C. Kershaw 261
Further Notes on the Refractory Properties of Zirconia. By H. Conrad Meyer 263
The Dedication of the New Building of the Mellon Institute. By W. A. Hamor 266
Personal 267
Obituary 267
Digest of Electrochemical U. S. Patents 268
Book Review 268

Why Play to the Galleries?

It never rains but it pours. If it is not a new and revolutionary invention in oil chemistry, it is at least an announcement of one. And the daily newspapers seem to be happy that besides the war they have something else they can write about without being troubled by scruples that come from too much knowledge.

At the February meeting of the American Institute of Mining Engineers in New York, Dr. Walter O. Snelling presented in the Petroleum and Gas Section informally a paper on gasoline from synthetic crude oils, relating some surprising and interesting observations. The paper was discussed in open meeting. An abstract was published in our last issue. The formal paper in full will be published in the next *Bulletin* of the Institute.

A fortnight later, on the first of March (it was not the first of April) the daily newspapers printed a remarkable interview with Secretary Lane in Washington, on two now celebrated oil inventions of Dr. Walter F. Rittman of the Bureau of Mines, and in the string of delightful newspaper stories which followed, an American dyestuff industry was created on paper under the protecting wings of the Bureau of Mines.

It is a pity that no official technical information was given out at the same time. We hope that Dr. Rittman's expectations will be realized—whoever knows him likes him. But whatever the future may bring, it is like a blow to the standing of the American chemical profession that the announcement of achievements of such alleged importance should have been made in a manner so unconventional according to professional standards. Claims should not be made unless proof is produced at the same time. First with radium and now with oil, the Bureau of Mines has been rather unlucky in the choice of its press agents.

A Spectacular Spelter Market

The daily market report on spelter has made interesting reading for a couple of months. It was anticipated, of course, that spelter would rise after the war started and authorities freely predicted seven-cent spelter. The predicted price has been exceeded and ten-cent spelter realized. The explanation lies in the fact that our domestic production and consumption have been about equal; and with foreign production greatly curtailed a tremendous export demand has been added to domestic needs. Add to this a certain hysteria that is likely to accompany such conditions, and we have the explanation of a runaway market. The inevitable slump has come and prices have receded, but will probably remain high during the war.

A review of average annual zinc prices for thirty

years past shows that the highest prices at New York was roundly seven cents for 1912. Prior to that the high average was about six and two-tenths cents for 1906. In no other year was the average annual price as high as six cents. Present prices are without comparison. The highest price ever paid for Joplin concentrates was reached early in February, when the basis for 60 per cent concentrates was $70 per ton, with premium grades bringing a higher price. Utah and Colorado operators have taken advantage of the situation and have been shipping low-grade ores. Of course such conditions could not last long. They work temporarily to the benefit of ore producers, but are not so acceptable to smelters who have to buy ore at a high price with the prospect of being able to sell the metal therefrom at a time when prices have receded from their high level. It was for this reason that zinc-ore producers who were without smelter contracts found it impossible to sell their ores at any price.

Illuminating Pig Iron Statistics

The official statistics of pig iron production are presented in such detail that some interesting conclusions can be derived as to trade movements and the character of material produced from the iron. The production in 1914 was 23,332,244 gross tons, making the year's tonnage 24.6 per cent under that of the record year, 1913; 1.4 per cent under that of the lean year, 1911; but 46.3 per cent in excess of the tonnage in 1908. So rapidly has the iron and steel industry grown, however, that the 1914 output was greater than that of any year preceding 1906, even though 1905 in its time was a year of great activity, and the output was more than quadruple that attained in 1886 or any preceding year.

The banner year for the Bessemer process was 1906. In years of relatively full demand, like 1912 and 1913, the character of the steel process employed is necessarily dictated largely by the facilities available, while in a year of light demand like 1914 the preferences of buyers have more influence, hence the following comparisons between 1906 and 1914 are quite illuminating:

PIG IRON PRODUCTION

	1906	1914	Change
Bessemer	13,840,518	7,859,127	—33.2%
Basic	5,018,674	9,670,687	+92.8%

Included in the tonnage reported as "Bessemer" is about 200,000 tons of low phosphorus iron, the precise output of which in 1914 has not yet been separately reported.

Of the Bessemer and low-phosphorus pig iron produced in 1914, 5,467,687 tons, or 69.5 per cent, was delivered molten, indicating almost universal and continuous employment of direct metal, except as prevented by the necessity of casting Sunday metal and metal for stock, as well as the shipment of iron between works under allied ownership. Of the total production of Bessemer and low-phosphorus iron in 1914, only 527,905 tons was made for sale. Doubtless this comprised nearly all the low-phosphorus iron, the remainder being almost exclusively iron sold for the manufacture of ingot molds. The major part of this iron is delivered molten, although sold, and with two additional plants now being built to use direct metal in making ingot molds the vogue of this process will become practically universal, even though the ownership of the mold foundries is entirely different from that of the furnaces which, under long-term sliding-scale contracts, furnish the molten pig iron. In the case of basic iron 6,436,146 tons, or 66.5 per cent, was delivered molten, leaving 3,234,541 tons that was cast, doubtless all in chills. There was 1,479,721 tons of basic iron made for sale, and it is doubtless accurate to deduct this tonnage, as having been cast, leaving it that 8,190,966 tons of basic iron was made for the consumption of the producers, all but 1,754,820 tons of this having been used direct, making 78.6 per cent of the makers' production used direct, an even larger percentage than obtained in the case of Bessemer iron.

A Suggestion in Patent Reform

Previous comments in this journal on needed reform in the United States patent system have made it apparent that the objections to our patent procedure lie not so much in the organic law as in the methods of enforcement of the contract between the government and the individual. In the development of our system it has suffered from the same practices that have received public disapproval in ordinary court procedure. Legal technicalities have supplanted in importance the economic aspects of a case, and legal form and procedure have almost attained the dignity of an end instead of a means.

The abuses which have thus found their inception and growth in the practice of adjudicating patent rights have led to the suggestion of a special court of patent appeals with revised rules of procedure and power of final decision. Even this excellent suggestion, however, concerns itself with improvement in the system *after* the patent has been granted, and offers no relief from obvious deficiencies in the system prior to and including the actual grant. The point is that probably much of the trouble now following the grant of a patent might be obviated by greater care in the granting.

Under present conditions a metallurgical or chemical patent in litigation has not received the careful attention of experts until it is called in question. Then it becomes the subject of a long investigation, and expert testimony is brought forward in great volume. The question arises: If experts are deemed necessary to settle a point in litigation, might they not be of equal value in passing scientifically on applications for patent? If, instead of submitting a patent to experts after it has been granted, it were subjected to scientific examination before granting, the prospective patentee might be relieved of much expense, delay and trouble, and would not feel that he had been deceived as to the nature and value of the covenant between himself and the government. Hoover comments on this phase of the matter in his book on Concentration by

Flotation, saying that "if the courts deprive him (the patentee) of the benefits definitely promised, someone has blundered. Every legal case in which the patents of one litigant are declared invalid is an indictment of the most serious nature against the system."

Another benefit that might result from scientific examination of patent applications would be the rejection of many supposed novel ideas of alleged usefulness. Many of these are scientifically unsound and claim results that are practically impossible of achievement. They merely clutter the record. Others contain alleged improvements and are often introduced by patent pirates and leeches. It is recognized, of course, as Hoover says, that "a new metallurgical process never springs fully developed from the brain of one person," and consequently many of the improvements are valuable. On the other hand, one has only to review the patents and litigation in one subject, such as flotation, to feel that if scientific experts reviewed the applications, many of them might not be granted. The situation would be freer from complications and progress in the industry would not suffer.

The Steel Corporation's Operations

Probably there was nothing occult in the coincidence that the thirteenth calendar year of the United States Steel Corporation's existence proved to be its worst in point of earnings. The earnings, $71,663,615, were not only the lowest, but were only 44.5 per cent of the earnings reported for the Corporation's best year, 1907. Allotted per ton of steel products made the earnings were $7.95 per ton, thus falling below the previous minimum, $8.65 in 1912, and thus being but 48 per cent of the highest average shown, that for 1902, $16.59 per ton. Roughly speaking, the decrease in earnings per ton in twelve years has been approximately equal to the decrease in steel prices, but the Corporation's expenses, particularly in the average rate of wages and in the amount of taxes paid have greatly increased. These, apparently, have been offset by refinements in manufacture and by carrying the products, on the whole, to a greater degree of finish.

In 1902, with practically full employment of all the Corporation's manufacturing facilities, the output of steel products, weighed in the form in which sold, was 8,033,556 tons, while in 1914 the output of 9,014,512 tons is stated to have represented only about 62 per cent of the capacity, indicating an increase of about 75 per cent in capacity in twelve years, making the present capacity about 14,500,000 tons. During this time the bonded indebtedness, including bonds held in sinking funds, has been increased by $345,000,000, while the preferred stock outstanding has been reduced by $150,000,000, making a net increase of $195,000,000 in the securities, an increase of 14 per cent. The actual value of plant facilities, per ton of finished steel capacity, has been very greatly increased, partly through refinements in manufacturing, for the production of the same material, and partly through the addition of finishing departments to carry steel to a higher degree of finish.

The Corporation's output of by-product coke in 1914 was 4,081,122 net tons, or 36.5 per cent of its total coke output, the highest proportion in its history, and comparing with a proportion of 6.1 per cent in 1907, the first year for which by-product coke was reported. The tonnage of Bessemer steel ingots was by far the smallest in the Corporation's history, only 4,151,510 gross tons, the proportions of ingot production being 35 per cent Bessemer and 65 per cent open-hearth. In 1902 the proportions were 69 per cent Bessemer and 31 per cent open-hearth. The relative productive capacity, however, has not changed so greatly, as in 1902 both Bessemer and open-hearth facilities were fully employed, while in 1914 there was a larger percentage of idleness in Bessemer than in open-hearth departments. It is entirely pertinent to observe, however, that in 1902, with full employment of the facilities, the open-hearth ingot production was 2,984,708 tons, while in 1914, with light employment, the production was 7,674,966 tons. The Corporation's maximum production of open-hearth ingots was 10,524,552 tons, in 1913.

While the total output of merchant steel was 12 per cent greater in 1914 than in 1902, the production of rails was 49 per cent less; tubing and pipe increased 23 per cent; sheets and tin plates increased 52 per cent, and there was a large increase in sundry products.

High-Grade Ore

There is no more spectacular incident in mining than the discovery of high-grade ore. It commands public attention, stimulates activity in prospecting and leasing, and brings visions of sudden wealth to the stockholders. There is a more sober side to the matter, however, that becomes painfully apparent when such ore is marketed. What is its true value and how shall it be determined? And when the value is ascertained, how shall the precious stuff be treated with minimum loss? The sampling and estimation of the value of high-grade ore is not a simple matter. Discrepancies rapidly mount into the thousands of dollars. Buyer and seller are far apart in their estimates, each sure that he is correct. The difference is so great that the common ground of agreement seems hopelessly unattainable. Both sides "play safe," knowing full well the chances of loss in the transaction.

The recent discovery of unusually rich ore in the Cresson mine in the Cripple Creek district was properly a cause of more than local excitement; but it is safe to say that before it was marketed it was the cause of considerable worry. It was originally sampled at a local sampling works and consigned to a Denver smelter where it was again sampled. The results of the two samplings were widely at variance, the reported difference of opinion representing about $40,000 on the shipment. A resample was made at the smelter, and although the shipper's control sample checked closely enough with that of the smelter to have brought about a settlement, there was still the wide discrepancy with the original sampling. Buyer and seller could not agree and the ore was removed elsewhere for sale and treatment. There are some compensations in the steady production and treatment of ore of medium grade.

Readers' Views and Comments

The Radium Situation

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In your March number Mr. Warren F. Bleecker makes a very remarkable statement which should not be permitted to go unchallenged by the chemists of this country. "There were," he says, "in this country no men who could determine radium quantitatively with any degree of accuracy," referring to the time when the Standard Chemical Company first entered the radium field. By those who have followed the development of radium from the beginning, who recall that practically all our knowledge of the quantitative relations of radium and radioactivity is based upon the work of Rutherford and Soddy at Montreal, who are familiar with the exact work of Boltwood at New Haven and of McCoy at Chicago, this statement will be taken for what it is worth, but it will no doubt afford comfort and solace to those curious individuals who take pleasure in depreciating what is nearest them.

With the substance, however, of Mr. Bleecker's paper I most heartily agree. If the Federal government goes into the radium business on the plea of monopoly, why not into the nickel business, and the manganese business, and the bread business, and every other business? Surely the interference of governmental agencies in private affairs has gone far enough for an English-speaking country. Stewart J. Lloyd.

University of Alabama,
University, Ala.

* * *

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I thank Professor Lloyd for calling attention to the statement made by me relative to the accurate quantitative determination of radium. This statement is in error and I am pleased to correct it at this time.

A further explanation of the situation to which I referred is as follows:

During the time mentioned, which was in the years of 1910 and 1911, the founders of the Standard Chemical Company endeavored to obtain, in this country, the services of men of standing and authority, to measure and investigate radium in carnotite ores; and to one or more laboratories at least, samples of carnotite ore were sent for measurement and for advice as to possible extraction processes.

When it is realized that in the working out of a commercial process, the number of radium determinations upon the raw ores, intermediate and final products is very large and that there is a great variation in the kind of samples necessary for controlling the work, one may easily imagine that this work could not be well done within the limits of a university laboratory however skilled the operator might be in making a research in which he is not limited as to time.

We were taught in the early days that it was usually necessary, in making a determination of radium, to allow the samples to stand until the emanation had reached its equilibrium value, which is four weeks. In the control of a metallurgical process it is easily seen that this is out of the question.

While I am very glad to correct the statement, which, taken literally, is obviously incorrect and unjust, I wish again to call attention to the difference in the point of view between those who are doing academic work and those who are engaged in applying data and conclusions so obtained in a commercial way.

Industrial concerns must always look to the great men of our universities to supply not only information about new things, but also to train a fair proportion of their students as far as possible in technique, so that when called upon, as they surely will be, to meet a demand for men to apply these things, it can be met safely and without embarrassment.

I had this situation in mind without realizing that a general statement relative to our peculiar relations to the measurement of radium, might cast reflection upon those who were in the work and upon whose researches we now base much of our knowledge about radium, as has justly been stated by Mr. Lloyd.

While Mr. Lloyd does not necessarily imply that we are of "those curious individuals who take pleasure in depreciating what is nearest them," it is but fair to say that it was not until July, 1912, that we were able to obtain the services of any one who was willing to come to our laboratory who had at the same time the ability to turn out results satisfactory for commercial work.

Further than this, we had previously had a gentleman with us who, without casting reflection upon the institution from which he was recommended, was unable to meet the requirements of his position. The only time I was able to get a positive statement from him as to the quantity of radium in any ore or product was just before his departure. Then he specifically told me that a resulting tailings product contained more radium than the ore from which it came, illustrating that his sense of humor was inversely in proportion to his ability to measure radium.

Standard Chemical Co.,
Canonsburg, Pa. Warren F. Bleecker.

Carbon Bricks for Plant Furnaces

To the Editor of Metallurgical & Chemical Engineering:

Sir:—Permit me to ask the readers of your journal if carbon bricks have been used as lining for common pig-iron blast furnaces, and if so, with what result?

It seems that such bricks of a good quality ought to serve the purpose rather well, as far as the bottom is concerned, judging from the results obtained in electric furnaces for similar purpose, where they have proved very satisfactory.

The material is cheap in comparison with some other refractories, and the wear and tear far less than what one should anticipate. Joh. Härden.

Guldsmedshyttan,
Sweden.

Comparisons of Electric Resistivities at High Temperatures

To the Editor Metallurgical and Chemical Engineering:

Sir:—In my article on the above subject in your January issue, Charts 1 and 2, page 24, there is an error in the curve for platinum. It is only in the exterpolated part, and as no values exist, the error is not important, but the figure nevertheless should be corrected.

Platinum melts at 1755 deg. C., and the figure for that metal should, therefore, rise abruptly and vertically at that temperature. No determinations, to my knowledge, have yet been made of the increase in resistivity of platinum at its melting point, nor even to show that it does increase; but presuming that it does, and assuming that, like most metals, the resistivity approximately doubles when the metal melts, the curve for platinum in Charts 1 and 2 should have been drawn accordingly. As this curve is merely exterpolated for

quite a wide range below its melting point, this correction is necessarily only very crude, though it seems to be the best information existing at present.

Philadelphia, Pa. CARL HERING.

Chemical Engineering Versus Engineering Chemistry

To the Editor of Metallurgical & Chemical Engineering:

Sir:—What's in a name? Perhaps but little; nevertheless, the writer, for one, has had some difficulty in seeing the difference between the two lines of activity implied in the title; and there are others at present who do not seem to realize that there is a difference. When I was a teacher of "pure" chemistry, the difference was not clear. When I had some of the hard, grueling experience of the University of Hard Knocks, I came to see what the difference is, and how tremendous it is.

Only recently I was asked, and by one of the prominent educators of the country, what is chemical engineering? To cut matters short, I told him that chemical engineering is industrial chemistry, which seemed to satisfy him; but, strictly speaking, the answer is by no means true. It is true that theory and practice in chemistry may merge into each other so that it is or may be hard to discriminate, at times; but in the large sense, chemical engineering ought to be more than engineering or industrial chemistry. But let us take an illustration.

The manufacture of sulphuric acid by the contact process, or rather by any one of them, can be worked out in the laboratory of pure chemistry. We may ascertain the substances involved in the special reactions used. We may test out the results by careful quantitative work. We may even go so far as to plan the design of commercial works for this process. We may be able to make some provisional and tentative estimates of costs and expenses. All this is good; it is essential; but it is only industrial or engineering chemistry.

The well-planned process becomes chemical engineering, only when it is carried over to the actual manufacturing conditions and results. Then there appear conditions which must be unknown to small dimensions and crude conditions of the experimental laboratory. When one enlarges apparatus from test-tube-and-beaker to small commercial size, there invariably appear new conditions and new troubles, unguessed and undreamed of at the earlier stage; and when one advances from small commercial size to true generous commercial dimensions, then other new and more vexing problems appear to be studied and solved on this large-scale plant. All this is so well known to the experienced engineer that it may seem not worth mentioning; but this common truism is not known, nor properly appreciated by the educators who are just waking up to the problems of establishing schools of real chemical engineering. I presume that it is something which can come only from hard and bitter experience—this realization of what engineering is, as distinct from the theory of what it ought to be, or might be. It seems to be what each one must learn for himself.

At what then shall the teacher of chemical engineering aim? It will be a safe theory to follow, to assume that the schools should try to give the student both the foundations, and also the immediate connections of these foundations with actual practice. I assume that the student has been given good and long training in the various branches of chemistry, together with the essentials of physics, mechanics, the "handy" acquaintance with mathematics, depending on his special aptitude in that much abused necessity, the basis of drafting, materials and this especially, a practical reading familiarity with French and German, and command of writing his ideas in commonsense English. But all this is only the preparation for the actual struggle now to come, the mastery of the principles of chemical engineering, and the practice of the chief processes involved in their application. Now it is easy to enumerate some of the eternal chemical processes; they include solution, mixing, precipitating, filtering, drying, conveying, distillation, etc.

Let us take the old process of filtering for example. The student should be required to take down, inspect and reassemble any one of the good old types of filter-press. He should be given the same course with some of the newer types, such as the remarkable Sweetland filter-press, which has been described in the pages of *Metallurgical and Chemical Engineering*. He should be taught to look out for new and progressive attempts to solve the problem of continuous filtration, illustrated, for example, by such a machine as the "Filtros" continuous filter, described on page 125 of the February, 1915, issue of this journal; and he should do it by means of a specimen of the new machine large enough to show its commercial use.

In all this the student must inevitably run across the business questions of power, labor, wages, etc., and he must be shown how to incorporate all this in his estimate of the special suitableness of the various types of filters for the special problems to be studied. And in deciding what is the best machine for the special material to be treated, there is no better rule than that of Mr. Edison, "If you want to find out a thing, try it."

And so on, with all the chief chemical processes—each must be studied with enough equipment to show what is being done, and what improvements are needed and possible.

But what of the fundamental chemical and mechanical principles involved in chemical engineering? What of the production; the transference; the use; the measurement of heat, electricity, power; what of all these? It goes without saying that they must be mastered, but would it not be well to have the student always master them in connection with the construction and use of some special machine or process? In this way the student will always have his attention focussed on the commercial use of his materials and methods.

But what of the questions to be faced in the title of this paper? What of the relations of engineering chemistry on the one hand, with chemical engineering on the other? I presume that for the schools of one kind it may be well to teach directly certain trades, such as dyeing, tanning, soap-making, sugar refining and the like. There is a call for young men so trained; and some of our most helpful schools, as the Pratt Institute, do such work, and do it well.

But for the higher type of graduate engineering, it may be well to query whether the best results will be reached by the special training in special trades. Here it would seem that the very thoroughness involved will show that the most and the best can be done by training, practical training, in both the processes and the principles involved and implied in the application of the laboratory to the factory. But this demands large equipment in power, buildings and machines, not to speak of the implied laboratory and shops accessory thereto.

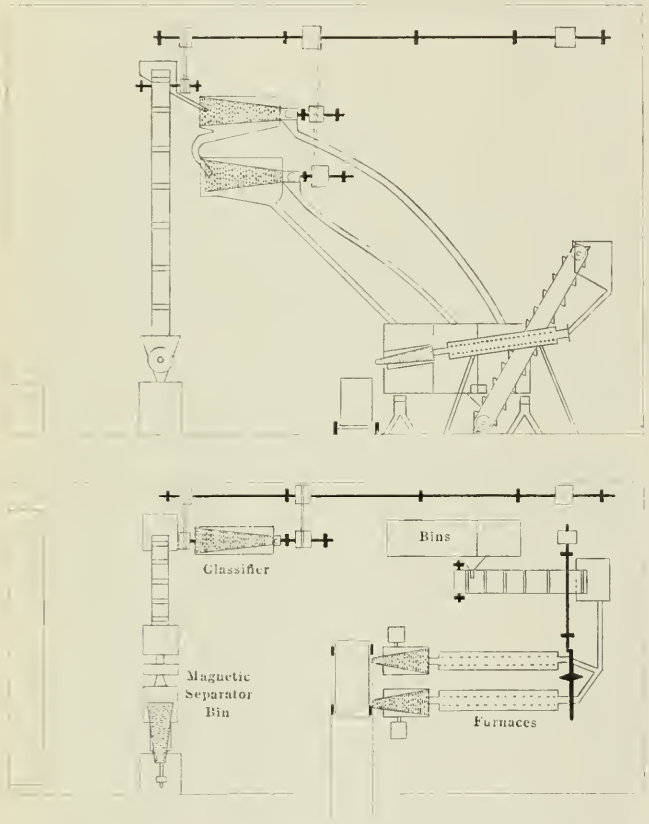
And this brings us to our conclusion, namely, that the chasm between engineering chemistry and chemical engineering must be closed up as fast and as thoroughly as possible. Not that it can ever be entirely bridged over, but the gap can be lessened and, by dint of wise and persistent effort, we may be able to put and keep the young enthusiast in closer touch with the engineering idea: "Go as far as you can see; and then see how far you can go." CHARLES S. PALMER.

Newtonville, Mass.

Separation of White Metal and Gunmetal Borings

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In locomotive machine shops there is produced a large quantity of gunmetal borings mixed with white metal, which, in certain cases, is very difficult to deal with. So far as we are aware the only method used for effecting a separation is liquation on an iron plate or in a furnace. This process is only suitable for coarse borings and absolutely useless for the finer grade material. Owing to the rapid accumulation of fine borings in the New South Wales Railway workshops it was necessary to devise a scheme for the recovery of these two classes of metal and keep them in circulation. This metal cannot be smelted straight out and used generally for castings on account of the high antimony content—0.6%. It could, perhaps, be used for a few special castings, but for general railway purposes, a mixture of this kind would probably soon lead to serious trouble.



ARRANGEMENT OF PLANT FOR THE SEPARATION OF WHITE METAL FROM GUNMETAL BORINGS

Under present conditions the borings taken from the machines are shaken on a ¼-inch mesh sieve and the coarse white metal separated from the gunmetal by liquation on an iron plate. The removal of the white metal in the fine borings is the problem we were asked to solve.

After a few experiments it was decided to pass the small borings from bin to a magnetic separator, pick them up by revolving belt fitted with pockets, and convey them to a bin above classifiers. From this bin the borings gravitate to classifiers and are separated into three grades. From bins Nos. 1 and 2 containing the coarser material, the borings gravitate on to a short revolving belt fitted with pockets and are delivered into a bin above the furnaces and here gravitate to the furnaces. These furnaces are constructed of iron tubes, one fitting inside the other. The outer one being several inches larger in diameter than the inner one, is supported by means of brackets to the floor and carries in the intervening space between the two tubes, a coil of iron pipe with suitable size perforations for heating the walls of the inner tube by gas. The inner tube is revolved and the hot borings and liquid white metal pass into revolving screens smaller in mesh than the last classifier, and the liquid white metal mixed with the borings allowed to escape through the screen into an outer vessel surrounding the screen, and which is heated by a gas coil. In this way the white metal does not cool, but collects at the bottom and can be run into moulds.

The clean borings pass along the screen into a hand truck on wheels, which can be taken to the foundry and the borings smelted and utilized for ordinary gunmetal castings.

The finest grade in No. 3 in., which is only a small percentage of the total, will probably have to be smelted and the bulk of the antimony got rid of by oxidation.

The sketch herewith shows the arrangement of the scheme suggested for the treatment of the above class of material at the railway workshops.

Bondi, Sydney,
New South Wales,
Australia.

R. H. Walton,
Gregory T. Bailey.

Tube-Milling in All-Slime Cyanide Practice

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I am much indebted to Mr. Haynes for putting in concrete form much that I would like to have said on closed-circuit tube-milling. As he shows, the cumulative load going to a tube-mill makes a preposterous proposition if the original load is more than the tube can grind. If it cannot fully grind the original 100 tons of battery pulp, it cannot grind 67 tons of return feed plus another 100 tons of new pulp.

It is contrary to all logic to overload any machine and then return the untreated part to the same machine. We went through that experience when the Wilfley and other concentrating tables came out. Every table was equipped with a return elevator for middlings. What became of those elevators? They promptly went to the scrap heap; and the solution of the middlings problem was found in separate treatment, regrinding and retreating on separate tables. In cement factories we find large tube-mills used. Do they use "closed circuit" or "open circuit?" Has it not been fully determined in roll-crushing plants that small sizes must be eliminated and sent to other rolls, and that it is not economy to grind several sizes in one machine? We see in Mexico that even in crushing for the making of *tequila* the fresh material goes to the first set of rolls and the partly crushed stuff to a second set. In fact, is it customary in any mechanical work of this kind to return an unfinished product to be treated with fresh material?

We then come back to the possible claim that the partly ground sand from a tube-mill is so easy to finish that on its return to the tube it is properly ground during the second cycle. If so, it shows that it would be better to work tube-mills in series, as quoted by Mr. Haynes in referring to the Liberty Bell mill. Sufficient tube-mill capacity has to be provided to do the required work, and I believe it will require more tube-mills to do the grinding in closed circuit than in open circuit in series, with an intermediate classifier. Indeed, I think that the work can be done with tubes in parallel, with open circuit, feeding a pulp of low-moisture content. I think that high-discharge mills necessitated high moisture; high moisture made poor grinding; poor grinding occasioned the return of unground pulp, and the return was wrongly made to the same tubes instead of additional ones. A tube-mill should have all the neces-

sary elements wherewith to grind in one cycle to the required degree of fineness. The varying positions of the ore particles with reference to the diameter of the mill, and the many sizes of pebbles in the charge, furnish a multitude of grinding conditions to fulfill all requirements. A tube-mill will grind new feed plus return pulp if the conditions be right; but it can grind only so much ore and an overload results in poor work.

A point that I have observed in tube-milling is that on feeding coarse mine rock for pebbles, the angular projections or corners are broken off quickly and accumulate in excess of the quantity required to fill the insterstitial spaces. They then discharge through the screen plate at the tail of the mill and if fed back by hand they continue to be discharged, since they form a cumulative load that the tube cannot grind. They must be taken up to the batteries in order to successfully dispose of them. When flint pebbles are used for grinders this condition does not exist, as the pebbles wear only in proportion to the grinding done. In fact, if a tube is started with large pebbles only, it will do very poor work until a sufficient number of small pebbles form to fill the voids.

Although not wholly pertinent to the discussion, I want to comment on the custom we have of referring to fine grinding in terms of "per cent through 200-mesh." It is an arbitrary and indefinite term, particularly because it gives no clue to the degree of fineness to which the whole pulp is ground. It tells nothing about the fraction that is not ground through 200-mesh, and very often it is this fraction that influences final extraction. If this fraction passes 150-mesh and the extraction is satisfactory, it would be better to use the term 150-mesh for the whole. If the fraction passes 150-mesh and the extraction is not satisfactory and can be made so only by grinding to 175 or 200-mesh, then that term should be used. In short, the practice of referring to "per cent through 200" leaves us in the dark regarding the coarser portion which, while it is not mentioned, may be the critical feature of the grinding.

I recall one plant in which we were treating 1000 or more tons daily. The final pulp going to the treatment vats averaged from 67 per cent to 70 per cent minus 200-mesh. The plus 200 caused poor extraction, occasioned high cost and stuck up the vats. Without changing the crushing and grinding equipment, we modified the classifiers and fed 30 per cent moisture pulp to the tubes. Classification was greatly improved, extraction increased, costs came down and no further trouble was experienced with the ore in the vats. Eighty per cent of the ore passed 200-mesh, and we still spoke of our grinding in terms of that figure. Would it not have been more significant if we had expressed our former grinding as 120-mesh and the latter as 175-mesh, rather than 68 per cent minus 200 and 80 per cent minus 200, respectively.

Guadalajara, Mexico. W. J. PENTLAND.

Grinding Ore for Cyanidation: A Suggested Modification for All-Slime Practice

To the Editor of Metallurgical & Chemical Engineering:

SIRS—I have been gratified to see that my contributions to the discussion of cyanide practice have evoked some comments, as shown by the articles of Mr. Pettis and Mr. Haynes in your January number. I am sure that a good deal has been overlooked in general practice by the failure to treat distinct parts of the ore according to their particular conditions or needs. It was not my intention to suggest or formulate a procedure applicable to all ores, but to call attention to the feature of giving particular treatment to different parts of the same ore.

The subject offers a large field for discussion. We have first the probability that there has been too pronounced a tendency to rush to all-sliming, overlooking the possibility that it might be advisable to leach all the sands, coarse and fine, or that the fine sand might better have agitation with or apart from the slime, and only the coarse sand leached.

The matter of removing concentratable material, either because of its injurious effect in consuming cyanide, or because it requires more elaborate treatment, has usually been duly investigated; but further investigation into the subject of segregating other parts of the ore has generally been overlooked, although the nature of the problem is the same.

My attention has been called to this subject by the experience of many mining companies in Mexico. Most of them began operations with ordinary battery crushing, concentration, slime agitation and sand leaching. The concentrates were shipped to smelters or cyanided separately. All sliming then came into vogue; slimey and sandy gangue matter yielded to agitation, but the old question regarding concentrates still survived. Most of the operators came to the conclusion that it was more economical to abandon concentration and to slime everything. This was a decided move in opposition to the idea of special treatment for different parts of the ore; but as any gain in ultimate economy is the final deciding factor, the change was to that extent an advance in method of treatment.

Many of these plants are now agitating for 48 hours, using 6, 7 or 8-lb. cyanide solution. Such treatment probably is called for by the concentrates and coarse sands, even though quite finely ground, and so all the ore receives the maximum treatment. Nevertheless, I believe that an advantage might be found in making a separation at the classifier, providing separate treatment for the slime and for the sand with accompanying concentrate, perhaps combining the two portions at some later stage after the sand and concentrate had received special treatment. Continuous treatment methods make many things possible that were impossible with intermittent methods. It would be quite a different matter to provide stock or storage tanks in which to accumulate several different kinds of pulp for subsequent treatment by an intermittent process.

Arrangement of plant for agitation of two products is not so complicated as might be thought. Suppose that slime and sand each comprise 50 per cent of an ore and that four agitators are in use. The slime from the classifier could flow direct to a thickener and thence to the last two agitators. The sand discharged from the tube-mill could flow through the first two agitators and then to the thickener, from which the combined pulp could then pass to the last two agitators. Thus the sandy portion would receive double the agitation of the slime. This scheme does not contemplate closed-circuit tube-milling; but for those operators who prefer that method a primary and secondary classifier would be necessary in order that the tube-mill discharge could be classified without mixing with fresh battery product.

Under this scheme, standardizing of agitating solution could be made where it would do the most good.

If it were desirable to separate coarse sand for leaching, that could be done by classifying the tube-mill discharge. If it happened that the slime were the part requiring more extended treatment, the system could be arranged accordingly.

It would, indeed, be strange if the cyanide process should prove to be the only method of ore-treatment wherein it were found desirable to treat the whole ore as one product rather than as two or more. In smelting we go to extremes in the mechanical handling of ores; smelting some just as they come from the mines; treat-

ing others by roasting, sintering, briquetting or other appropriate processes; recovering and re-treating flue-dust and other by-products. In concentration we classify and size without end, and regrind and reconcentrate middlings. And yet cyanide operators sometimes try to do the whole thing in one operation, on the assumption that the simpler the process the more economical. Is not too much being expected of that simple solvent, cyanide?

All-sliming of concentratable ores and agitation of the total ore as one product, undoubtedly gave better economical results than did concentration, slime agitation and sand leachings, or the plants would not have been changed. But did not the operators go one step too far when they decided to agitate all the products together, making the conditions of treatment for the most refractory part be guide for the whole ore?

Guadalajara, Mexico. W. J. Pentland.

The Danger of Throwing Inventions Open to the Public

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The public press now teems with statements regarding the new inventions and developments of Dr. Rittman and their importance. The announcement is made that these discoveries, after patenting, would be thrown open to all. This, if true, does not offer much hope that they will be adopted and developed for the reason that the value of a patent usually or at least often lies, not in establishing a monopoly in the patent itself, but in the incidental protection it affords to those who do the missionary work, that is the effort and money expended in developing it and making a market for the product.

It has already been stated that about the surest way to prevent the development of a new invention or process is to throw it open to anyone who chooses to practice it. If any competitor may adopt and use the means and appropriate the knowledge gained in developing an invention and marketing its product one seldom feels disposed to embark in the work, but if he does, then he must generally conduct it as a secret process if any suitable profit is to be expected.

It is a long way and one not often traveled from the conception of a truly original invention or even from the issuing of a patent therefor, to a profit from its use. If it is what might be called a secondary invention representing a minor advance in some article or method already commercially established the case is of course different and the invention may be in full use before the patent is applied for.

What the public wants is for meritorious inventions or improvements to be made and then put to use. An invention to be adopted must offer a substantial increase in value or service over what has occupied the field it aims to work in, and if the inventor gets for himself even a small fraction of the increase or saving which results, he is fortunate. His share will never be great enough to deter anyone from working the improvement.

If Dr. Rittman's inventions work in with the established methods of parties doing business in the allied lines, they may, of course, be taken up by such parties, but if they are of revolutionary character then the encouragement for their development and working, without protection, becomes small. Old business is naturally conservative, and a new invention which threatens if adopted to "scrap" existing plants, wholly or in large part, will usually be unwelcome until possibly its acceptance is forced by the march of events. The working up of the revolutionary invention must then be undertaken, if at all, by newcomers in the business with the chances against success.

Dr. Rittman might therefore promote the general good better and induce the introduction of his inventions quicker if he remains in position to afford pioneers in their development such protection that those who lie low waiting for others to show the way would not be able to come in later and reap where they had not sown. The only way for him to do this is to retain the patent rights for himself, or his assigns.

In this connection it might be said that if some legal way existed by which a business enterprise which develops and produces new goods could be protected from unfair imitation and competition when patent protection cannot be obtained, it would seemingly inure to the advancement of the arts and the public welfare. A new thing is not necessarily patentable.

Plainfield, N. J. Henry D. Hibbard.

The Western Metallurgical Field

Smelter-Smoke Litigation in California

The vagaries of smelter-smoke litigation are well illustrated in some of the cases that have hampered the smelting industry of California. In Shasta county, in the northern part of the state, the farmers succeeded in closing all the smelters except that of the Mammoth Copper Mining Co., which continued in operation under a system of neutralization of acid gases, and bag-house collection of dust and fume. By the method employed, which was described in Metallurgical and Chemical Engineering for December, 1914, the company was enabled to keep within the terms of the court decree relating to the composition of discharged smoke. Farther south, in the vicinity of San Francisco, the Selby Smelting & Lead Co. finally had its troubles satisfactorily adjusted through a commission, which found that the terms of the court decree were being substantially complied with. During the troublous times for these companies, however, the Penn Mining Co., operating a copper smelter at Campo Seco, in Calaveras county, was left undisturbed. Apparently its time has now come, for no fewer than 35 suits are reported to have been filed against it by the farmers in the immediate vicinity.

Some time since California had a state commission, appointed by the governor, to investigate the smelter-smoke situation. In their report, made about the end of 1914, they found that conditions around the Mammoth smelter were unfavorable, despite previous judgment to the contrary; but no strikingly unfavorable report was made as to Campo Seco and the Penn company. Hence, the latest developments are strangely unaccountable. The federal court has within less than a month again denied an injunction against the Mammoth company, in which the farmers alleged a violation of the decree; and since the first of this year 35 suits have been filed against the Penn company. Evidently the state commission, the federal court and the farmers are not in accord. It is rumored that covetous lawyers have stirred up the trouble among the hitherto satisfied farmers around Campo Seco, and have piled up suits for damage aggregating over $300,000, expecting to make their fortune through contingent fees. The scheme is old and moth-eaten. It worked in the early days of smelter-smoke litigation, when the smelters compromised and paid for real and alleged damage until the condition became unbearable; but it can scarcely be taken seriously in this day of scientific investigation of such damage. Such suits cost tremendous sums of money, requiring the services of many experts; and it is safe to say that smelters probably are much better posted as to genuine damage caused by smelter smoke than are a

group of farmers misled by lawyers. When the latter learn what it costs to secure the necessary testimony to support their cases, interest in the contingent fees is likely to wane.

Reduced Shipments from Cobalt in 1914

According to figures prepared by Mr. A. A. Cole, mining engineer for the Temiskaming and Northern Ontario Railway Commission, the bullion shipments from Cobalt, Ontario, during 1914 amounted to 9,624,629 ounces of silver, valued at $5,254,097. Compared with the shipments for 1913, there was a decrease last year of about 200,000 ounces, due mainly to disturbances in the mining industry caused by the war. The decrease in value of the 1914 output as compared with that of 1913 was about $600,000, due to the low price of silver prevailing during the last year. The Nipissing company contributed nearly 75 per cent of the total bullion output, amounting to over 600,000 ounces; but this was lower than for 1913 by nearly 230,000 ounces. The Buffalo company was second, with a total of over 900,000 ounces. This also was lower than for the preceding year, as the company operated only for the first seven months of the year. On the other hand, the Dominion Reduction and O'Brien companies showed substantial increases over 1913, as did also some other companies. Kerr Lake showed the greatest increase, producing over 400,000 ounces in 1914, as against 50,000 in 1913. The following list gives the shipment and value of bullion as compiled for 1914 by Mr. Cole:

Company	Ounces	Value
Bailey	1,353.95	$785.27
Beaver	9,849.00	5,004.09
Buffalo	912,250.00	500,013.35
Casey Cobalt	2,566.64	1,343.72
City of Cobalt	27,341.64	15,523.75
Cobalt Comet	1,597.54	923.65
Cobalt Townsite	36,538.86	19,580.17
Crown Reserve	626,374.00	343,822.52
Dominion Reduction	726,397.85	405,885.50
Foster Cobalt	2,157.13	1,017.62
Hargraves	794.00	414.81
Kerr Lake	407,238.53	183,970.15
La Rose	55,365.48	29,066.87
McKinley-Darragh	17,470.00	10,016.55
Nipissing & Customs	6,299,677.75	3,469,526.13
O'Brien	452,822.00	243,933.91
Penn-Canadian	16,454.94	8,839.69
Temiskaming	6,163.70	3,553.20
Toownsite-City	17,640.35	8,465.83
Trethewey	4,576.04	2,409.86
	9,624,629.40	$5,254,096.64

In the latter part of February the Nipissing company made one of the largest shipments of bullion in its history. The consignment comprised 320 bars containing 376,709 fine ounces of silver, valued at $183,645. The shipment followed the period of annual clean-up at the mills, and brings the total bullion shipments for 1915 past 1,000,000 ounces. Ore shipments from the Cobalt district, however, were low during February, amounting to only 995 tons of ore and concentrates. This is the lowest monthly shipment in seven years, and is also the first in which the monthly shipment has fallen below the 1000-ton mark. The decrease is ascribed to shortage of power during the month.

Progress with the cyanide plant annex to the concentrating mill of the Cobalt Reduction Company is being rapidly made; the building has been completed and the cyanide machinery is being installed.

Anaconda and Butte-Duluth

It is reported that the Anaconda Copper Mining Co. has failed to exercise its option on the mining and metallurgical property of the Butte-Duluth Mining Co. The failure to exercise the option seems not to have interfered with further negotiations with new interests, and it is announced that a new 60-day option has been given another concern. Anaconda is reported to have found the mine and leaching plant satisfactory, but disagreed with Butte-Duluth on the terms of sale.

Federal Mining Experiment Stations

The bill to establish ten mining experiment stations in the mining states, for the purpose of making investigations in the interest of better metallurgy, passed both houses of Congress and has been signed by the President. As no appropriation was provided in the bill, its terms cannot be put into effect at this time.

Company Reports

The report of the **Arizona Copper Co.** for the year ended September 30, 1914, shows a production of 38,942,455 lb. of copper, compared with 34,230,000 lb. for the previous year. Due to the lower price received for copper in 1914, the profit fell off over $700,000, a considerable proportion of which is directly attributed to the outbreak of the war. Drastic reduction in output was made directly following declaration of war, but in view of the recent improvement in demand, the production has been increased since January 1. Dividends for the year amounted to about $645,000. The sulphide concentrating department handled 932,945 tons of concentrating ore. The average ratio of concentration was 8.42:1. No. 6 concentrator was enlarged during the year and now has a capacity of about 3000 tons in 24 hours, but is not now running full time. The oxide concentrator and leaching plant treated 87,875 tons of ore, producing 5414 tons of concentrate, which was sent to the smelter. The leaching plant handled 72,649 tons of tailing.

The sulphuric acid plant supplied the leaching plant with 2937 tons of acid. Including ore treated at the old smelter during the first quarter, there was smelted 182,873 tons of ore and concentrate. The average yield of copper from this material was 10.65 per cent. The new smelting plant is reported to be working satisfactorily.

Butte & Superior Copper Company's report for the fourth quarter of 1914 shows the following operating data:

	Fourth Quarter	Third Quarter
Dry tons of ore milled	33,520	100,600
Average zinc content (per cent)	19.4538	18.582
Average silver content (oz. per ton)	8.9286	8.6359
Zinc concentrates produced (pounds)	20,464,000	60,974,968
Average zinc in concentrates (per cent)	53.947	54.32
Total zinc in concentrates (pounds)	11,039,557	33,121,312
Average silver in zinc concentrates (oz. per ton)	23.54	24.15
Mill recovery (per cent)	84.65	89.14
Mining cost per ton	$3.288	$3.201
Milling cost per ton	$2.466	$2.049
Total cost per ton, mining and milling	$5.754	$5.25

The low tonnage and production for the fourth quarter were due to closing the mill from October 17 to December 17. During this period extensive repairs were made and considerable remodeling done in the mill. Seven new cells were added to the flotation plant. The financial statement shows profit of $130,537.

The Trethewey Silver Cobalt Mines, Ltd., produced during the calendar year 1914 a total of 527,097 oz. of silver, valued at $251,843, as compared with the 1913 production of 619,429 oz., valued at $333,611. Ore reserve is estimated as equivalent to one year's production. The average price received for silver in 1914 was 6.08 cents lower than for 1913. The mill cost was $1.31 per ton, being 15 cents lower than for 1913. Shipments comprised 298 tons of concentrates averaging 1577.7 oz. silver per ton and 314 tons averaging 217.78 oz.

The Crown-Reserve Mining Co., Ltd., shows in its annual report for 1914 a production of 1,425,320 oz.

silver of a gross value of $740,092. On account of the low price of silver and the war the receipts were probably $100,000 lower than the same quantity of bullion would have produced in 1913. The milling record shows the treatment of 31,347 tons of ore, from which an average of 15 oz. per ton was returned. The total cost per ton was $4.16. The average value of high-grade shipping ore was $3,474. The cost of producing silver per ounce was 28.95 cents and the profit 22.97 cents. Dividends paid amounted to $424,515.

The Porcupine-Crown Mines, Ltd., which is controlled by the Crown-Reserve company, shows a production of gold during 1914 valued at $691,394 from 40,857 tons of ore of an average value of $17.65 per ton. Referring to mill operations, the report states: "The continuous decantation process has not only been justified but has proved remarkably adapted to the ores of the Porcupine district and, with one exception, has been adopted by all the important mines in the district. The average extraction of the mill for the year was 97.26 per cent." The cost of mill operation is given as $1.31 per ton. The estimated value of ore reserves is $1,500,000. Dividends paid amounted to 12 per cent, or $240,000.

The Non-Ferrous Metal Market

The general state of the non-ferrous metal market during March was one of confusion and uncertainty. Spelter continued its phenomenal rise to a point of collapse, but copper, lead and tin were firmer. The price of tin advanced decidedly, owing to scarcity of foreign supply.

Copper.—A good demand has existed, especially among domestic brass manufacturers, and the market is considered in a fairly strong position. During the early part of the month the price rose to 14.75 cents per pound, New York, with the prospect that it might go higher.

Lead.—Although domestic demand has continued rather light, foreign consumption is rather heavy and large shipments have been made abroad. The A. S. & R. Co. raised its price to 3.90 cents on March 1 and to 3.95 cents on March 5. The latest St. Louis quotations were 3.87½@3.92½.

Tin.—Prices varied widely at the beginning of the month, rising as high as 48 cents. Domestic demand was slack and the advance in price was ascribed to anticipation of shortage of supply due to disturbance in the shipping situation. Following the rise, prices fell to about 45 cents, New York.

Spelter.—The spectacular advance in this market apparently culminated early in March, and although prices have not yet become settled they are on the decline. Metal for prompt delivery was scarce and brought fancy prices. Metal for June delivery was offered at 8 cents. The nominal New York quotation last available was about 7.75@8 cents; St. Louis, 7.60 @7.75.

Other Metals.—Quotations for aluminum continue about 19@19¼ cents per pound, New York. A shortage in antimony again raised prices, different brands bringing from 21 to 27 cents per pound. Quicksilver also is up, $65 being paid for flasks of 75 lb. at New York and $60 to $63 at San Francisco.

The New York Section of the American Institute of Mining Engineers will hold its next meeting on Wednesday, April 7, at the Machinery Club, 50 Church Street. Dinner will be taken at 6.30 and afterwards a discussion will be held on the economic side of safety and sanitation as applied to the mining and metallurgical industry.

The Iron and Steel Market

At the close of March the steel mills were operating at an average rate of fully 65 per cent of their ingot capacity, though naturally at a somewhat lower rate measured in terms of finishing capacity, as finishing capacity always exceeds steel-making capacity. The average rate in March was close to 65 per cent, against about 55 per cent in February, 45 per cent in January and 35 per cent in December. The improvement in trade opinion of the prospects, what is commonly denominated in market reports the "sentiment," began about the first week in November. The improvement in buying began in December, while the increase in production began about January 1. The improvement has been continuous. In March the increase in orders placed and in the rate of production was relatively slight, while the improvement in "sentiment" was decidedly marked. This decided improvement in the trade's hopes for its future was due chiefly to recognition of the fact that when a steel-trade improvement has lasted over a period of about four months it is entitled to a great measure of respect. The little spurts to which the trade has grown accustomed in recent years have been matters of a couple of months.

The alignment of demand for steel products has been quite abnormal. It is a remarkable thing to see the steel industry operating at practically two-thirds of its capacity when scarcely any railroad material is being made and when there is very little structural work in progress. In certain branches of the finished steel trade there has been almost full employment. The tin plate mills have operated at about 85 per cent of capacity in the past three months, substantially as heavy a rate as has ever been seen in a first quarter. The wire mills, with a very fair domestic demand and with an abnormally large export demand, have operated almost at capacity in February and March. The pipe mills have had nearly a full demand for standard pipe, while demand for line pipe has been only fair, and demand for boiler tubes and oil country goods has been extremely light. Less than 10 per cent of the total steel produced in March was for eventual railroad consumption, whereas the average of the past few years has been 15 to 20 per cent and in earlier years the proportion of railroad steel was still larger.

A detailed scrutiny of the steel market indicates rather plainly that there is no prospect of any decrease in demand from the rate of the past month, while there may easily be a slight increase merely from seasonal conditions. For any decided improvement over present conditions one thing is absolutely necessary, and that is a loosening of funds for permanent investment in railroad extensions and betterments and in bridges, buildings and manufacturing extensions of various sorts. The demand thus far experienced, apart from the export demand and the demand for shipbuilding material, has been confined almost exclusively to materials for common everyday consumption for wire and tin plate, for instance, as contrasted with rails, steel car material and structural shapes. The latest thought in the steel trade, which is strengthening the favorable views entertained for the future, is that there may be within a few months a loosening in investment funds through anticipation of an early termination of the European conflict.

Pig Iron

One of those movements for which the Buffalo pig-iron market is becoming noted occurred late in March, a total of perhaps 150,000 tons of Buffalo iron being sold for second quarter and later delivery, at an average of about $11.75, f.o.b. Buffalo furnace. Apparently,

however, the movement was not due so much to a change in fundamental industrial conditions or to the buyers taking the initiative, but rather to the sellers dropping their prices and indicating that it was necessary for buyers to act promptly. After the Buffalo movement of last November, at about $12, the furnaces advanced prices about $1 a ton and have thus had room lately for making reductions. Other markets which had fair sales at that time did not advance and thus there are no facilities for arousing the interest of buyers in such markets. Apart from the Buffalo movement the pig-iron market continues dull and colorless—disappointing indeed since a large volume of contracts should expire April 1 while the evidences are that the tonnages have not been taken out as rapidly as the contracts contemplated. The market is quotable as follows: No. 2 foundry: Delivered Philadelphia, $14; f.o.b. furnace, Buffalo, $11.75 to $12; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13; f.o.b. Birmingham, $9.25 to $9.50; f.o.b. valley furnaces, 95 cents higher, delivered Pittsburgh: Bessemer, $13.60; basic, $12.50; No. 2 foundry, $12.75 to $13.25; malleable, $12.75; gray forge, $12.50 to $12.75.

Steel

After a period of extreme inactivity some inquiry for billets and sheet bars developed late in March, for second quarter, and slightly higher prices were quoted than had been nominally in vogue for prompt shipment, about $18.50 for billets and $19 for sheet bars, f.o.b. maker's mill, Youngstown. There is practically no market being made in Pittsburgh, and the delivered Pittsburgh price is about a dollar a ton above the Youngstown basis. Deliveries on contracts were much heavier in March than in February. Rods are $25 to $26, Pittsburgh.

Finished Steel

The 1.10c. price for bars, plates and shapes disappeared March 1 according to program, leaving the market at 1.15c. for March and 1.20c. for second quarter, there being, of course, some exceptions when large lots for specific jobs were involved. The beginning of April, it is now hoped, will see a disappearance of the 1.15c. quotation. Sales of galvanized sheets at the mill price of 3.40c. have been extremely light. For one thing, many jobbers had contracts at much lower prices, made before the phenomenal advance in spelter, and became competitors of the mills, while for another thing consumers are quite averse to paying such high prices for galvanized sheets and if spelter does not decline sufficiently to permit galvanized sheets being sold at prices somewhat in harmony with those of the past the consumption will be materially reduced.

Current quotations are as follows for ordinary deliveries, quotations being f.o.b. Pittsburgh unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.15c. to 1.20c.

Shapes, 1.15c. to 1.20c.

Steel bars and bands, 1.15c. to 1.20c., base; hoops, 1.25c. to 1.30c., base.

Refined iron bars, 1.15c., Pittsburgh; common iron bars, 1.12½c., Philadelphia; 1.12½c., Chicago.

Sheets, blue annealed, 10-gage, 1.30c.; black, 28-gage, 1.80c. to 1.90c.; galvanized, 28-gage, 3.40c.; painted corrugated, 28-gage, 2c.; galvanized corrugated, 28-gage, 3.45c.

Tin plate, $3.20 to $3.35 for 100-lb. cokes.

Steel pipe, 80 per cent off list.

Steel boiler tubes, 3½ to 4½ in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Cold-rolled shafting, 70 per cent off list of March 15, 1915, f.o.b. Pittsburgh.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Chain, ⅜-in. proof coil, 3c.

Conditions in Mexico

The best impressions we can get regarding conditions in Mexico come from private correspondence that filters through on occasional mails. It is difficult, if not impossible, to draw general conclusions even from such sources, but they at least represent the daily happenings and are suggestive of the troublous times through which Mexico is passing. Commerce and industry must necessarily be at a standstill under the changing domination of conflicting parties, and mining is out of the question. The following excerpts from the correspondence of a managing engineer now at Guadalajara, Jalisco, covering a period of time from Jan. 10 to Feb. 25, show in a graphic manner the state of lawlessness that exists. They express the hope of the inhabitants in the "Villistas" and their fear of the "Carrancistas."

Jan. 10, 1915.

"We have had no violent experiences since the last attempt of the Villistas to enter the city at night, which was quickly repulsed. That was on the 30th of December, I think. For the last three days the Carrancistas have been getting ready to leave; some trains have left, but there are a great many of their troops still here. They have loaded enormous quantities of baggage and household furniture on the trains. We know nothing of the movements of opposing forces, but never lack for rumors of all kinds. This city is in a desperate state and the population in a state of dread all the time. Martial law in due form would be better than a disorganized state such as we have now.

"Some time back they ordered all rifles to be turned in. Foreigners were ordered to turn theirs in to their respective consulates. The authorities attempted to take possession of the arms in the consulates, and the Germans and French delivered theirs on a show of force. ———— sealed his consulate doors and went out of sight so as to avoid a discussion. The authorities attempted to force ———— to deliver up the British arms but he refused. They stood him up to shoot him and he dared them to go ahead. Then he sealed his doors and told them to break them down if they chose to do so. We admire his spirit, but if they go ahead and break his doors, they will also those of the American consulate. If bloodshed once starts over it, that will be the last of all of us, as they will then know that they have put their foot in it and might as well make a good job of it. They hung a railroad man last evening and shot another because the men did not wish to serve on the trains."

Jan. 31, 1915.

"Our latest has been an attempt by Julian to retrieve his lost fortunes and take this city from the Carrancistas. I guess he thinks that if Villa has to come over to take it again he will put some other *hombre* on the job as governor, seeing that Julian lost out after having been seated on the throne.

"Saturday, 30th, at 5.15 a. m., we heard one of the d—— shootings that we have yet been treated to—and it has to be something out of the ordinary these days if it is to attract attention. They came into town by every road available, and if they had had any head they would have had the place, as every cut-throat thought his time had come. Some yell, that, "Viva Villa," to judge by its effects. But somehow advantages were not utilized, and in the end Julian and his took up their quarters on the outside again. Some excitement, though, for disinterested people, these daylight attacks. Makes it bad about the cooking, as the *criadas* do not come to work for a day or two.

"About noon a cannon got working against the packing house where it was supposed some of the outsiders had taken refuge. Do not know what damage they did to the packing house, but they killed old ————, the moonshiner who lived at the defunct distillery near by. We know nothing of the outside world; mails, telegraphs and trains are dead."

Feb. 8, 1915.

"Today is another red letter day with all the excitement that goes with big doings. The Carrancistas are on the move again—another evacuation—and the grabbing of things belonging to other people makes us stay at home and keep the back gate shut securely.

"Last night troops were moving all night, and we knew that something was in the air. It is said that the Villistas have taken Colima.

"We have quite a time with the paper money. Diequez would not permit any Villa money to circulate, so that his own stuff should have the preference. This morning Villa paper is already being received in general. Everybody wears a glad smile this morning, even though they are fearful of what might happen before this crowd leaves. Exchange has been around eight and nine for one lately, but little business done of course. I do not believe I would buv up much for speculation if I had lots of idle money.

"Unless relief comes to this country soon there is going to be some actual human suffering for the needs of ordinary daily life. If one could believe that the experience of the people would do them some good in making them realize the responsibilities of life and country, there might be some consolation in the reflection; but reasoning powers they have not nor ever will have, so it becomes a matter of cruelty to animals."

Feb. 11, 1915.

"No change of scene; just the same old terror existing. Yesterday I saw part of a fracas in which one of these high-binders found a petty excuse for using his gun, and shot a man at the Casino below the American Club. We heard two shots, saw the victim run and fall at the corner, get up and stagger around while the high-binder looked for a chance to aim his pistol again. Our friend ———— stepped in between, as did also ————. Many others came running up, and they induced the victim to go to the palace where it was finally determined that he was not to blame. The governor was sorry, and the high-binder went away without being able to finish his story.

"Last night they shot two women on the street for being out after 8 p. m., and not being able to tell a good story quickly. Today they threatened some clerks because they declined to take some bad bills. I saw the soldiers go in after them. They said this afternoon that the clerks had been shot, but I could not confirm the story.

"This morning the brewery cashier declined to change a bad bill—said he had no change. Complaint was made and the soldiers went after him and made him open the safe, when it was found that he had lots of change. They fined the brewery a thousand *pesos*, and when payment was offered in their own money, they refused the bills as being bad money.

"Most of the high-binders have been living on their trains for the last several days, ready to move; but for some unknown reason they remain. How the people would like to see this bunch get out, and a set of real devils come in in their place, so that the city could have a little peace. I never thought that I could live in such an atmosphere as we have had here of late. What we go through every day would be the event of a life-time in the States. People are so thoroughly terrified that no one dares talk with anyone not an American or an Englishman. Our noble American Consul has been in hiding for three days; and today we see that a notice has been pasted on the door stating that affairs of our consulate have been turned over to the British Consul."

Feb. 13, 1915.

"Well, they put us on the map again today. Villa came in with a small bodyguard of cavalry, and the ovation he got from the city was something to be remembered. The American Consul came out of hiding this morning, and was around telling why he hid and left his *nationales* orphans. An old federal judge, Delgado, is said to be slated for governor. Poor Julian lost his job. Villa is supposed to have sent a lot of men after Dieguez, and will finish him now as he should have done in December. Our spirits have come up greatly since noon. Perhaps we shall be permitted to live a while longer."

Feb. 17, 1915.

"We have had several days of speculation as to what the new outfit would be able to do to the outs. Villa himself is at the front, and we imagine that they are doing some real fighting. Villa has an aeroplane with him. It left here yesterday morning and got part way to the front.

"We hear that Villa has declared the country cut in two parts, and that the line runs from below Manzanillo to below Tampico. That puts us in the north, for which we are thankful. All of us are now figuring on when we can do something. These folks are now busy cleaning up the town of traces of Carrancistas. I guess that they get away with a good many of them, and I hope they get the last of them and make good Indians of them.

"They say that Julian will have his job back after all, and I would rather he did, as we are better off if we have someone that we know personally. He has been expected in town for a day or so, but his feet must have been sore from the brush run that he made, and so he has been slow getting back. Dieguez took away everything in the way of an engine that could be moved, and those that could not be moved he tried to ruin. He broke up the railway shops and raised Cain generally so they cannot rustle engines for traffic. If Dieguez ever gets back here, it's good-bye Guadalajara."

Feb. 25, 1915.

"I have your letters of Nov. 11, Jan. 11 and 25, all having come in a few days ago by the first train bringing mail for some time. Having ventured out toward our diggings, I was gone a few days and so have not written immediately. I got within speaking distance of the mines, that is, speaking over the telephone forty miles. That is doing fairly well, though, considering the circumstances.

"The Southern Pacific track from Orendain to La Quemada consists of two streaks of rust and a mushroom bed; at least the rotten wood that was formerly ties can serve now only for planting mushrooms. They have not had a new tie in over a year, and whenever they rustle a car of ties, some military train comes along and takes them for fuel. They have a locomotive, two cars, a conductor and engineer at La Quemada, but none of them can be moved as there is no oil for the engine, and the crew is looking for something to eat.

"We really know nothing of what is going on in the country. There has been heavy fighting down toward Colima, but what the result is we know not, and people are fearful that the old crowd may return some day. Our only satisfaction, and it may be an illusion, is that living is extraordinarily cheap for those of us that are on gold salaries. The poor devils that are on a *peso* basis are in a bad way. The natives also are in a bad way, as prices are frightfully high, and but little work to be had.

"Trains go out toward Irapuato frequently, and some come in, so mail is moving somewhat; but any day we may be cut off. If you get no mail from me in a long time, you may take it for granted that there has been a change of play and a new film on. If the Carrancistas get back into this place, our cake will be all dough."

Atlantic City Meeting of the American Electrochemical Society

The annual meeting of the American Electrochemical Society will be held in Atlantic City from Thursday to Saturday, April 22 to 24, 1915. The headquarters will be at the Hotel Chalfonte.

Sessions for the reading and discussion of papers will be held on Thursday afternoon and Friday morning and afternoon. On Thursday evening Professor William S. Franklin of Lehigh University will lecture on models of electromagnetic phenomena. On Friday evening an informal smoker will be held.

On Saturday morning a train will be taken to Philadelphia and sessions will be held in the morning and afternoon at the Harrison Chemical Laboratories of the University of Pennsylvania. Between the sessions lunch will be taken at Houston Hall. In the afternoon session a lecture will be delivered by Provost Edgar F. Smith of the University of Pennsylvania.

New Orleans Meeting of the American Chemical Society

The fiftieth meeting of the American Chemical Society will be held at New Orleans, La., from Wednesday, March 31, to Saturday, April 3, 1915. Headquarters are at the Hotel Grunewald.

The feature of the convention will be a general meeting on April, in which nineteen different papers will be presented in the contributions of the chemist to different industries. The opening address will be made by Dr. A. D. Little, of Boston, on the industrial resources and opportunities of the South, while in the evening Dr. Bernhard C. Hesse will speak on the chemists' contribution to the industrial development of the United States.

The Electrochemical Production of Organic Compounds

The New York Section of the American Electrochemical Society held the fourth regular meeting of the season at the Chemists' Club on the evening of Feb. 5. This was a joint meeting with the New York sections of the American Chemical Society and the Society of Chemical Industry. The evening was devoted to a symposium of papers on the electrochemical production of organic compounds.

Introductory Remarks

Dr. COLIN G. FINK, chairman of the New York Section of the American Electrochemical Society, introduced the subject by the following remarks:

"The subject of organic electrochemistry is a new one in America. If you will look over the membership list of the American Electrochemical Society you will find that most of the members are metallurgists and inorganic chemists. Another large percentage is composed of electrical and mining engineers. The organic chemists form a very small group.

"The subject of organic electrochemistry is a very important one, yet owing to an unfortunate tendency on the part of the organic chemist to shun physical chemistry and a like tendency on the part of the electrochemist to shun things organic, the field of organic electrochemistry has been badly neglected. However, it was not the electrochemist who chose the inorganic lines but rather the inorganic chemists and engineers were induced to adopt electrochemical methods—methods which at first often seemed very impractical but eventually superseded all others. It was only a few years ago when the making of steel in the electric furnace was ridiculed by almost every chemist and engineer.

"There are three distinct reasons for introducing the subject of organic electrochemistry at this time:

"(1) In consequence of the European war the coal-tar industry in this country has received a great impetus.

"(2) Our European contemporaries, notably Elbs and his co-workers, have demonstrated conclusively that a large number of organic compounds, can be better and easier produced by electrochemical means than by any other.

"(3) Many of the electrochemical processes for inorganic products have been standardized and the electrochemist is looking for new fields to invade."

The Commercial Aspects of Organic Electrochemistry

Mr. F. AUSTIN LIDBURY, manager of the Oldbury Electrochemical Company of Niagara Falls and president of the American Electrochemical Society, presented a paper on the commercial aspects of electrochemistry.

Mr. Lidbury drew attention to the fact that the present disturbed conditions, which have thrown this country upon its own resources to a large extent, had made clear the brilliant position of the country in regard to its electrochemical industries; while quite another adjective would have to be applied in reference to the organic chemical industries. The reason for this was to be found largely in the fact that American Industrial genius ran along lines favorable to the development of the former, and unfavorable to the development of the latter.

It had been assumed by some that it would be an easy and natural matter for electrochemists to extend their triumphs in inorganic lines to organic lines; but with this view the speaker did not agree. With a relatively few exceptions, the obvious applications of electrochemical methods to organic industry (putting aside the use of electrochemical products such as chlorine, caustic, sodium, carbide, etc., in organic industry) were largely confined to the conversion of one intermediate product into another intermediate product; and as in such cases it would rarely happen that the electrochemist could feel on safe ground either as to his supply of the raw intermediate product, or as to the market for his finished intermediate product, the electrochemist was usually too much of a business man to enter a field of that kind. Consequently it must be left largely to the organic chemist, since it was under his purview that the commercial aspects of such change of products came.

The speaker compared, on the basis of reductions and oxidations equivalent to a gram molecular weight of hydrogen, energy costs involved in electrolytic methods with power taken at various figures, with the cost of chemical reducing and oxidizing materials. He showed that under most conditions a fair margin apparently existed, with the exception of the very cheapest reducing materials, such as iron, in favor of electrochemical methods. The difference was particularly marked in the case of oxidations, and the same remark would, of course, apply to substitutions.

However, two facts were to be set against this. In the first place, to do a unit of chemical work in unit time an electrolytic plant would usually be very much larger than a chemical plant; require very much more room; be very much more expensive; require more expert attention, and on account of the extreme severity of the demands of electrolytic methods on materials employed for plant, etc., the upkeep would also usually be higher.

In the second place, the working out of an electrolytic method requires a very much greater amount of time, thought intelligence and expenditure than the working out of a chemical method. Though this might not amount to much as regards laboratory investigation, anyone acquainted with the electrolytic industries would be aware of the greater difficulties which invariably had to be overcome in preparing such a process for large-scale operation, and in that important phase known as "establishing practice."

While American industries led the world in the application of intelligence to such industrial problems as were conducted on a sufficiently large scale, we had apparently not yet reached the stage where the same grade of intelligence was being applied to problems of smaller dimensions. This was one of the principal reasons for the difference in success between the inorganic electrochemical and the synthetic organic chemical industries in this country. It would be one of the things militating against a considerable adoption of electrochemical methods in the organic industries, as most of these applications would relate to problems individually of small commercial importance.

Lastly, Mr. Lidbury expressed considerable doubt as to whether organic chemists would be capable of themselves applying electrolytic methods to their own problems. An organic chemist was usually constitutionally unfitted to be any other kind of a chemist. It was, therefore, his recommendation that where there appeared to be a field for application of electrolytic methods, electrochemists should be employed for investigation purposes; and that they should be given not merely a specific problem to work out, but the run of the whole particular field involved, since electrochemistry was not so much a collection of methods as a habit of thought.

Electrolytic Preparation of Organic Compounds

The next paper was presented by Dr. HAROLD HIBBERT, of the Mellon Institute of Industrial Research on "the electrolytic preparation of organic compounds."

A review of the literature and patents published during the last twenty-five years brings out one fact very clearly, namely, that, as in so many other branches of

the chemical industry, the honor of being the pioneer in this development of the art belongs, one might say, almost exclusively to Germany. During the period under review (up to the end of 1910) some eighty-nine patents on this subject were granted in Germany, six in France, three in England and four in this country.

An analysis of the eighty-nine German patents shows that some fifty of these are concerned with the synthesis of dye-stuffs, or intermediate products concerned in the manufacture of dye-stuffs, as indicated in the following table:

Subject.	Total Number of Patents
Reduction of aromatic nitro compounds	39
(a) Reduction of nitro derivatives to give azo and hydrazo compounds	13
(b) Nitro derivatives to give amines (aniline, benzidine, m. phenylene, diamine, etc.)	6
(c) Nitro derivatives into nitroso compounds	1
(d) Nitro derivatives into amido phenols	12
(e) Reduction of azo and hydrazo derivatives to give amines (benzidine, etc.)	6
(f) Reduction of azo derivatives to give hydrazo compounds	1
	39

In addition to these patents there are between ten and fifteen concerned with the synthesis of various special products, as, for instance, the reduction of indigo, oxidation of alizarin and the direct formation of azo dye-stuffs.

The remaining patents have reference to various minor applications, such as the manufacture of iodoform, saccharin, vanillin, phthalic acid, etc. It will be noted that only in a very few instances has it been found possible to apply the electrochemical methods to the synthesis of aliphatic compounds.

In the author's opinion the wonderful progress associated with the caustic alkali-chlorine industry is to be connected principally with two factors: (1) The entire absence of a monopoly of the raw product. (2) The general demand in practically every branch of the chemical industry for these products.

Three factors are necessary for the development of any (synthetic organic) chemical industry: (1) Cheap fuel. (2) Cheap transportation. (3) Other factors, e.g.: (*a*) An ample supply of raw material obtainable at a sufficiently low cost; (*b*) satisfactory patent protection; (*c*) absence of inimical legislation.

In the writer's opinion there would seem to be no question but that a very considerable number of intermediate products required in the synthetic-dye industry could be manufactured in this country with satisfactory financial returns. It is of interest that the German patents on the principal processes have already lapsed. While most of the patents issued up to the present are concerned either with processes of oxidation or reduction, there would seem to be also a considerable field for the application of electrolytic processes to the synthesis of "substitution" products, that is, to the manufacture of chlorinated compounds of various descriptions, etc., but this will require an extended study of the technique suitable to the particular problem to be solved. However, in view of the great desire on the part of the electrochemists to find an outlet for the surplus chlorine produced in the manufacture of caustic alkali, it would seem probable that before long attention will be directed to this field as a possible outlet. Of the various processes, which have already been shown to be highly profitable commercially, coming to the writer's knowledge, those of iodoform and para-hydroxy-amino compounds would seem to form the most striking instances.

The best process for making iodoform would seem to be that developed by Foerster and Mewes.[1] A solution containing five parts of sodium carbonate, seventeen parts potassium iodide, ten parts 96 per cent alcohol and 100 parts water are electrolyzed, using smooth sheet platinum as anode and sheet lead as cathode. The temperature is maintained at 60-70 deg. C., with a current density of 1-2 amp per square decimeter. In order to avoid losses, due to reduction, the cathode is covered with parchment paper. Carbon dioxide is conducted into the solution at such a rate that this retains a distinctly yellow color. Iodoform settles at the bottom of the vessel in a perfectly pure state and, employing a current density of 1 amp per square decimeter, a yield of 95-97 per cent, calculated on the current used, is obtained. One kilowatt-hour gives about 500 grams of iodoform.

Apparently the simplest process for the preparation of amino phenols would seem to be that of F. Darmstaedter,[2] which consists in electrolyzing a suspension of nitro benzol in 50 per cent aqueous sulphuric acid. The two poles are separated by a diaphragm and it is necessary to agitate very vigorously. The cathode consists of carbon, the anode of platinum and a current density of 6 amp per square decimeter is employed. Using an excess of nitro benzol, it is stated that a yield of para-hydroxy-amino phenol up to 86 per cent can be obtained.

Another possible application of electrochemical methods would seem to lie in the utilization, for example, of waste dilute nitric acid for the manufacture of nitro compounds, as for instance the manufacture of nitro naphthalene according to Tryller's method,[3] which consists in agitating vigorously one part of molten naphthalene with fifty parts of dilute nitric acid at a temperature of around 82-85 per cent C. The electrolysis is carried out using a platinum cathode and aluminium anode. It is not necessary to use a diaphragm. The mononitro derivative, practically free from dinitro, is obtained in this way.

The Electrolysis of Aromatic Compounds

Dr. George Shannon Forbes, of Harvard University, presented a paper on "The Electrolysis of Aromatic Compounds," which was illustrated in a very interesting way by numerous experiments.

The typical reactions in the electrolysis of aromatic compounds are oxidation, substitution and reduction. Typical oxidations are those of aniline to aniline black, and indigo white to indigo (the first recorded experiment of this kind, Grotthus, 1807) which were demonstrated by Dr. Forbes by experiment. Important financially are such reactions as the oxidation of benzene to quinone, with subsequent reduction to hydroquinone, the oxidation of anthracene to anthroquinone, and that of o-toluene-sulphamide to saccharin.

In substitution an ion like Cl' or Br' may be discharged and act directly, or through migration of anions, like SO_4'', NO_3', or NO_2' the concentration of a molecular species may become so great on the surface of the anode as to cause reaction. This was illustrated by the preparation of Orange II.

Electrolytic reduction was illustrated by the preparation of azobenzene from nitrobenzene at a nickel cathode, and by the reduction of pyridine to piperidine at a lead cathode. The familiar scheme of reduction of nitrobenzene both in alkaline and in acid solution was discussed.

The great number of variables in electrolysis, such as electrode material, overvoltage, current density, catalysis by the electrode or by dissolved substance, the differing effects of temperature on primary and secondary reactions, added to the variables significant in ordinary organic work, make the situation very complicated, but in these very complications lies the possibility of preparing compounds from costly materials, with greater efficiency and profit than is possible by the ordinary methods of organic chemistry. It appears probable that

[1] Zeit. f. Electrochemie 4, 268, 1897

[2] D. R. P. 181,116 (1903).

[3] D. R. P. 100,417 (1897).

in cases like this, the difficulties and disadvantages of the electrochemical method will be outweighed, and that electrochemical methods will prove of the greatest value.

A general discussion of the subject followed in which Messrs. Bogart, Baskerville, Doremus, Richards, Hooker, MacDowal and others participated.

The Fixation of Atmospheric Nitrogen*

BY W. S. LANDIS

Chief Technologist, American Cyanamid Company

I assume more or less familiarity with the use of nitrogen in one or more of its various combinations, for even a partial catalog of the most common commercial nitrogen compounds would read like a few pages out of *Olsen's Chemical Annual* or the *Chemiker Kalender*. I will not even give statistics of consumption of the nitrogen compounds, because the very complex nature of these statistics would make them difficult of comprehension if merely read from prepared tables. I need but say that in tonnage alone the nitrogen compounds stand well at the head of the list of the world's trade in heavy chemicals, nitrate of soda and sulphate of ammonia being produced in 1913, to the value of $200,000,000.

Chilian Saltpeter and Coke-Oven Ammonia

Not including atmospheric nitrogen, whose utilization is yet in its infancy, we are practically dependent for our supply of this valuable element upon the nitrate deposits of Chile and upon its recovery as a by-product from our fuels. The Chilian deposits have been so frequently and fully described elsewhere that we can omit reference to the same here. The end of this source of supply is, however, in sight, and it will only be a few years until Chilian nitrate will pass into history along with our anthracite coal and the Saxon silver-lead ores.

The recovery of ammonia as a by-product from fuel is entirely different, for in the coke oven and the gas producer we will have an ever-increasing source of this element for many centuries to come, from which it is obtained in one of its most valuable forms of combination, ammonia. This source of supply is, however, somewhat unsatisfactory, inasmuch as it is wholly a by-product of the coal distillation industry, a ton of coal yielding only 5 to 6 lb. of ammonia, and by-products as a source of primary supply have many limitations. This is well illustrated by the present status in Germany, from which country I have lately returned. There is in that country just now a considerable shortage of nitrogenous fertilizer because the Government has confiscated all stores of nitrate for military purposes. (The fertilizer industry there consumes about 800,000 tons of nitrate per year.) The coke ovens which we should expect would normally come to the rescue in such a crisis are, however, largely closed. Ammonium sulphate production is, therefore, correspondingly decreased just at a time when agriculture needs it most, and its lack is felt acutely. Since my return I have learned that the use of coal has been prohibited in Germany in order to force the use of coke and thus increase the supply of ammonia and tar.

We came very near having the same conditions arising in this country, for were the farmer in position to take his normal fertilizer requirements there would be a great sulphate shortage, as our own industrial depression has closed down many of our coke ovens, and we would have no ready means of meeting even a normal demand for sulphate. We thus see the disadvantage of a by-product source of such an important element as nitrogen, and we understand why inventors have turned so actively to finding a substitute for the Chilian nitrate and the coke-oven ammonia.

Fixation of Atmospheric Nitrogen

Naturally the inexhaustible store of atmospheric nitrogen has presented itself most prominently in this search for a new source. Neglecting the many proposals which have merely wasted much paper and ink in describing impossible methods for the fixation of our atmospheric nitrogen, I am going to devote my attention solely to the successful and at the present time commercially developed efforts in this field.

We can classify these successful attempts into three groups:

1. Direct synthesis of nitrogen and hydrogen to ammonia.
2. Combustion of nitrogen and oxygen in the electric arc.
3. Combination of nitrogen with metals or carbides.

Synthetic Ammonia

The only commercial process to-day, belonging to group 1, is the so-called Haber process. Dr. Bernthsen (this journal, Vol. X, p. 637, 1912) described this process at the Eighth International Congress of Applied Chemistry, and exhibited a small working model of the apparatus. I am sorry that I can add but little to the technical information he there presented, but the owners of this process have maintained the greatest secrecy with respect to its commercial development, and but little is known regarding the details in the commercial world.

As you will recall, this process consists in passing a mixture of three volumes of hydrogen and one volume of nitrogen, at a pressure of upward of 150 atmospheres over a suitable catalyzer operating at a temperature of some 500-700 deg. C. A single passage of this mixture through the apparatus causes a transformation of 2 per cent to 6 per cent of the nitrogen to ammonia, which is recovered from the apparatus by condensation and the rest of the uncombined gases are again returned to the cycle.

Too much honor cannot be shown the courageous chemists who have succeeded in placing this process on a commercial working basis. The difficulties seemed almost insurmountable. The catalyzer, which has taken various forms and compounds, principally metals and carbides, poisons very readily, and, therefore, extreme care must be taken in the purification of the gases. Purity which the average chemist would classify as C. P. finds no place in this industry, as that would lack almost as much of meeting the requirements of the process as the use of crude chemicals in the analytical laboratory. It took years of work to find a suitable metallic container for the high-pressure gas mixture, because of the permeability of most ordinary materials. However, most of these difficulties have been overcome, and I have been reliably informed that the Badische plant at Oppau supplied its allotted quota of sulphate to the German Sulphate Sales Company last year, but I greatly doubt that they did it at a profit if it was made from synthetically produced ammonia, with sulphate prices as low as they were in the early part of 1914.

This process as ordinarily understood is not supposed to involve the use of any considerable quantity of electric power (which is not quite true), but does require a large amount of highly skilled labor, for the units are small and complicated. This particularly suits it to the Rhine location, but renders its value in the United States rather questionable. I personally cannot see a future

*A paper presented before the Washington Section of the American Chemical Society on March 17th, 1915, and before the Philadelphia Section of the American Chemical Society on March 18th, 1915.

for its operation under American conditions, particularly in view of the competition of the much cheaper cyanamid process which furnishes the same end product—ammonia.

At Oppau the Badische company must dispose of large quantities of waste sulphuric acid and have a by-product hydrogen, hence local conditions favor the Haber process above all others.

Direct Combination of the Nitrogen and Oxygen in the Air

The second group of processes embraces those oxidizing the nitrogen of the atmosphere in the electric arc. It is well known that when air is heated to temperatures of about 1800 deg. C., the nitrogen oxidizes to NO and remains, on rapid cooling, in that form. At that temperature, however, the reaction velocity is very low and commercial working requires that temperatures of above 3000 deg. C. be used, at which temperature the reaction velocity becomes quite considerable.

Three types of apparatus are in commercial use for performing this reaction:

1. The drum furnace with disk arc, of Birkeland and Eyde.
2. The long tube furnace with spiral arc, of Schönherr.
3. The narrow furnace with fan-shaped arc, of Pauling.

There are numerous other proposed types of apparatus which are claimed to be superior to the above, as reference to patent literature in particular will show, but the above listed three furnaces are the only ones in actual every-day operation.

The product obtained by passing air through the arc of any of these furnaces consists of a highly heated gas containing from 1 to 2 volume per cent of nitric oxide. On cooling down to temperatures of approximately 600 deg. C., this nitric oxide unites with free oxygen to form nitrogen peroxide, NO_2; on further cooling of this nitrogen peroxide to below 140 deg. C., it polymerizes to N_2O_4. When brought into contact with water and oxygen this reacts forming a mixture of equal molecular parts of nitric and nitrous acids. By subjecting the nitrous acid to further action of the peroxide this is also changed to nitric acid with the liberation of nitric oxide, which again passes through the cycle.

Thus by suitable cooling of the nitric oxide in the presence of air and water one ultimately attains a product which consists almost quantitatively of nitric acid, and actual operating results of the large furnace plants have shown a steady recovery of about 90 per cent of the nitrogen oxides in the form of nitric acid or nitrate salts, the remainder being received as nitrite or not absorbed.

In general the handling of the nitrose gases from the arc furnaces is now well standardized, and the design of a condensation plant is almost as well understood to-day as that of a sulphuric acid plant. After passing the various systems of cooling apparatus, consisting of steam boilers, evaporators, etc., the gases enter aluminium condensers where the temperature is reduced to approximately 100 deg. C. They then enter a preliminary oxidation chamber so proportioned that they remain in the same at least one and one-half minutes before leaving, where the preliminary oxidation to peroxide takes place. The gases next pass into a series of four or five stoneware or granite towers where they are washed with water by a counter current system, remaining in the tower system for from three to five minutes. Of the nitrogen oxidized 90 per cent is here condensed as nitric acid, the most concentrated acid being obtained in the first tower, and averaging from 30 to 35 per cent HNO_3. After passing these condensing towers the gases usually enter a final tower fed with caustic soda liquor, where a further 3 to 5 per cent of the oxidized nitrogen is recovered as sodium nitrite. The remaining 5 per cent passes out into the air unabsorbed.

As above mentioned, these towers deliver a 30 to 35 per cent nitric acid; this can be further concentrated to 50 per cent nitric acid, using the heat of the hot gases issuing from the arc furnace to perform the necessary evaporation. It is not possible to carry this evaporation much above 50 per cent for economical reasons, and where higher concentration of nitric acid is demanded special complicated concentration processes must be employed.

Dilute nitric acid, as obtained from the towers, finds little use in industrial processes, and it is difficult to transport. Most of the nitric acid plants, therefore, either concentrate it to 96 per cent acid by special means, or convert it into calcium nitrate for fertilizer use, or into ammonium nitrate for explosive purposes. In the latter case most of the ammonia used to-day in the nitric acid plants, operating on the arc system, is obtained from cyanamid.

It is quite probable that calcium nitrate will soon disappear from the fertilizer market as it certainly cannot be sold at a profit in competition with Chilian nitrate or ammonium sulphate even when the latter is made from cyanamid.

As we shall see later these arc processes require enormous quantities of cheap electric energy, and must be located near such power centers. We have no cheap power in the United States, and there is no immediate prospect of our having an arc process in continuous large-scale operation within our borders. Our Western powers are far from markets and transportation of the nitric acid as such to the East is almost out of the question.

Cyanamid Process

The third group of processes, as catalogued in my introduction, embraces fixing nitrogen by metals or carbides, and has reached its highest development in the cyanamid process, which last year produced throughout the world in the fourteen factories at present in operation, some 300,000 tons of material, carrying over 20 per cent nitrogen.

The inventors of the cyanamid process originally attempted the synthesis of cyanides by subjecting barium carbide to the action of nitrogen, which, as is well known, forms barium cyanide. On attempting to use the cheaper calcium carbide in place of barium carbide, Professors Frank and Caro found that instead of obtaining cyanide they obtained a new material, which proved to be calcium cyanamid. It was later found that this material could be utilized directly in agriculture, and from this discovery has grown the enormous cyanamid industry which has proven itself to be the cheapest method of fixing atmospheric nitrogen at present in existence.

Reference to the literature existing upon the manufacture of cyanamid seems to lead one to suppose that it is a comparatively simple matter to carry out the reaction so frequently written:

$$CaC_2 + N_2 = CaCN_2 + C.$$

This might be true to a limited extent were this the only reaction that we chemists at Niagara had to contend with, but I can merely say to you that even this reaction itself it so complicated that while it is well known that it is a reversible one, no one has yet succeeded in correctly establishing its equilibrium constants. A laboratory study of this reaction has been

carried out both in this country by Prof. M. de Kay Thompson (this journal, Vol. VIII, p. 617 and 687, 1910), and abroad by Professor Haber, but neither of them has succeeded in mastering the same, because of the peculiar difficulties that arise in a study of it.

Naturally if the highly skilled chemical laboratories have met with these difficulties, we can assume that practice runs against a few of them itself. But aside from the fundamental absorption reaction, as written above, there are a number of other complications that arise in this industry which we have to meet with in our every-day work, and which I shall call to your attention to show that the actual carrying out of the cyanamid process requires something more than writing the reaction on a piece of paper.

The fertilizer industry, into which most of our material at present goes, is a rather peculiar one, and probably has more peculiar fads and precedents than almost any other highly developed industry in the country. Naturally to sell to fertilizer men material we must take into account all of the peculiarities of the industry, and we must satisfy them—a fact which further complicates the cyanamid industry itself. But it may be assumed that inasmuch as cyanamid is being produced and sold at the rate previously mentioned we have succeeded somewhat in meeting these fancies.

The first stage of the cyanamid process involves the production of calcium carbide. To produce day after day a high-grade calcium carbide that meets the peculiar requirements of the cyanamid industry is quite an art in itself. There are no journeymen carbide workmen in our country, and we had to start out and develop our own furnaces and methods of operation. We had to seek sources of raw materials for this manufacture, which are quite different even from those which meet the requirements of the manufacture of lighting carbide, and we have to operate our furnaces in a certain peculiar way in order to combine these raw materials into a product of such structure and grade that we can make cyanamid out of it successfully. As may be recalled, Moissan in his early work found that he could not nitrify certain kinds of carbide, showing that there are conditions existing in our carbide manufacture that are different from those in the manufacture of lighting carbide.

Our next great problem was to grind this special grade of calcium carbide so that it passes a hundred-mesh screen. Naturally this must be done without slacking the carbide, as hydrated lime does not make good cyanamid. Now 100-mesh carbide dust is almost as explosive as low-grade dynamite when exposed to the atmosphere on a damp day, or thrown out on damp ground, so that it is quite some little problem of itself to grind this carbide to the required degree of fineness and have a mill left at the end of the day's run.

Next comes the production of nitrogen. It is a comparatively simple matter for the chemist to make a few cubic centimeters of high-grade nitrogen in his laboratory, but if one were to call upon him for 2,000,000 cu. ft. of a practically pure nitrogen per day, such as we make at Niagara, he would probably have to do considerable research to find out just how this enormous quantity of such high-grade material could be made. In the early days of the cyanamid process, when the Ni-

FIG. 1—AMERICAN CYANAMID COMPANY'S WORKS AT NIAGARA FALLS—LIME PLANT AT THE EXTREME RIGHT; COAL-GAS PLANT AT THE EXTREME LEFT; CARBIDE AND CYANAMID BUILDINGS IN CENTER

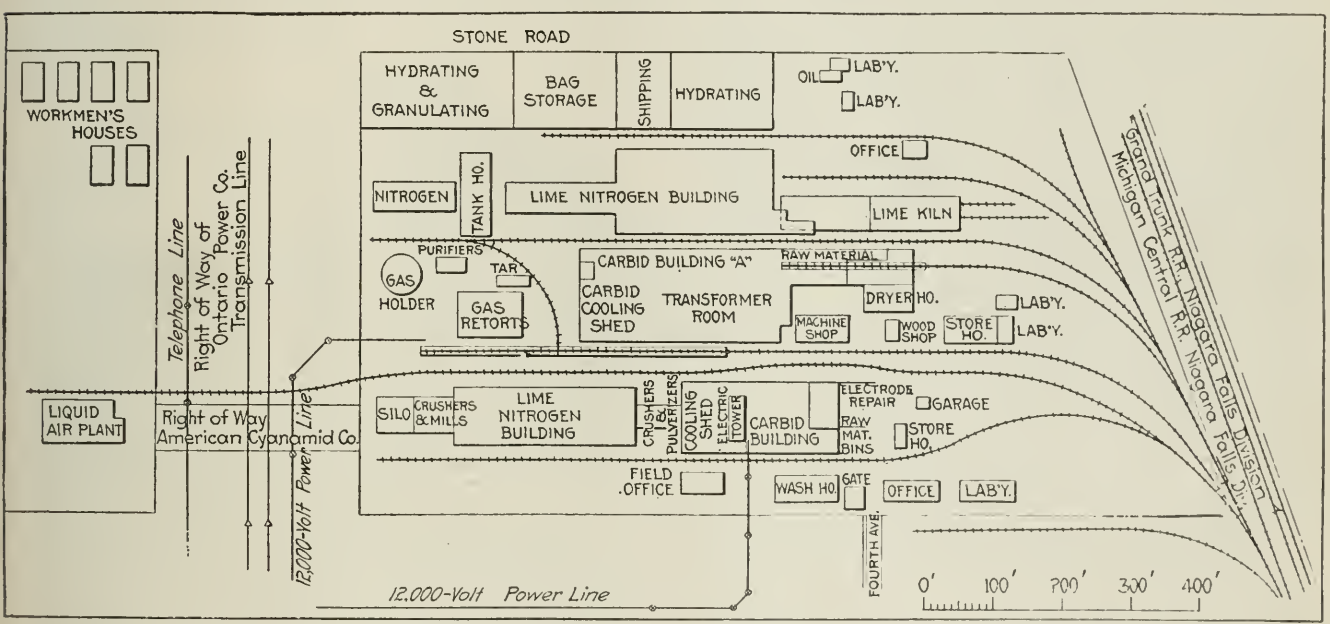


FIG. 2—PLAN OF AMERICAN CYANAMID COMPANY'S WORKS AT NIAGARA FALLS, ONTARIO

agara plant started, liquid air machinery was in a rather backward state of development, and we were forced to make our nitrogen by passing air over copper. The original plant was later enlarged. It was a long step from the combustion tube of the chemical laboratory to our present plant using retorts containing 5 tons of copper mass, but the problem has been successfully solved, and the new plant has been in operation with a minimum of trouble for some years.

In the early days of the industry at Niagara we could draw upon natural gas for reducing our copper oxide, so as to revivify it, but this gas supply has since failed and we were forced to put up our own coal gas plant. Even this coal gas plant is not a standard one, inasmuch as we are coking coal, not only for the production of gas, but also to furnish the coke for our carbide furnaces. We are running at temperatures in our retorts and obtaining qualities of coke and gas that the average city gas plant would not consider as possible of attainment, and it was only after considerable experiment that we ourselves demonstrated that our theories were correct in this respect and succeeded in finding gas engineers liberal-minded enough to incorporate our ideas into a working plant.

Eventually we had to install purification apparatus for taking out the impurities in the nitrogen, as it came from the copper retorts, and have equipped ourselves with soda towers for removal of carbon dioxide, refrigeration plants for drying, lime tanks for purification, etc., and have even developed this plant so highly that we have included a causticizing plant for recovery of our spent alkali.

After the development of the liquid air machinery, both in the way of capacity and reliability, the problem of producing pure nitrogen was much simplified, and our latest addition at Niagara includes what was probably the largest liquid air plant in the world at the time it was built, a year ago. This plant alone throws to waste almost 30 gal. of liquid air an hour, just to keep the apparatus flushed out and in good working order, not to speak of the thousands of cubic feet of rich oxygen-nitrogen mixture.

After one has overcome the difficulties in the production of a proper grade of nitrogen and of carbide, the next step is exposing these two to mutual reaction at a proper temperature, which is done in small individual ovens, holding from ½ to 2½ tons of carbide. The reaction itself is reversible, and particular precautions must be taken to always keep it running in the right direction until the carbide has all been nitrified. The physical and chemical conditions which must be met with in this part of our work are very complex.

The product removed from these ovens is a black, hard cake, which analyzes 22 per cent nitrogen and about 1 per cent un-nitrified carbide. This material, which we call "lime nitrogen," is next finely ground and stored in silos. The carbon set free in the reaction previously indicated is in the form of graphite, and it is not an easy proposition to find a satisfactory mill that will grind this material fine and at the same time not blow itself up from liberated acetylene derived from the presence of any uncombined carbide, or wear itself out grinding the lime nitrogen-graphite mixture. Extreme precautions are taken in this part of our operation, both in the mills themselves and in the elevating and conveying apparatus connected with them to avoid dangerous explosions, but I can truthfully say that in the years I have been connected with the company not a single injury has resulted from such explosions in our plant.

To prepare the lime nitrogen for agricultural purposes the finely ground material is partly hydrated to insure decomposition of the carbide it contains, and is then oiled to render it dustless, and stored in bulk, or packed immediately into sacks and shipped to the fertilizer mixer.

Calcium cyanamid tends to transform itself into a large number of organic compounds when subjected to the action of water, particularly at temperatures above normal, and, therefore, this hydration has proven an extremely complex problem, because we desire to avoid any such transformation, as agricultural experiments have shown that the calcium cyanamid in its unaltered form yields the best crop results.

Ammonia from Cyanamid

But agricultural uses are not the only purposes to which the cyanamid can be applied, as it is a very simple matter to convert the cyanamid into ammonia by the exothermic reaction

$$CaCN_2 + 3H_2O = 2NH_3 + CaCO_3.$$

If lime nitrogen is mixed in a slurry with water and subjected to the action of heat and high pressure, it is converted quantitatively into ammonia. In this country this use of cyanamid was not developed on a large scale outside our experimental laboratory until the beginning of this year, but while I was in Germany I saw in the yards of a big manufacturing concern there some sixty autoclaves, each capable of converting 10 tons of cyanamid into ammonia per day. This equipment was waiting railroad cars to move it out, and was in no sense experimental, because three similar plants have been in operation in Germany for at least three years. The cost of this transformation is hardly appreciable, and the purity of the product is quite high, requiring merely passing through a self-acting rectifying column for the removal of steam.

A New Ammonia-Phosphate Fertilizer

The ammonia so produced abroad is at present converted into a high-grade sulphate and a pure nitrate, and we are at work now in this country on producing a new fertilizer material, "ammophos," consisting largely of ammonium phosphate; my experimental laboratory at present working day and night trying to meet initial demands for this new material. Agricultural results the past season have been so phenomenal that our friends will not await the completion of a large plant for meeting the requirements, but have insisted on our converting our laboratories into a miniature factory.

Our product contains over 13 per cent NH_3 and 45-50 per cent P_2O_5, or over 60 per cent plant food, the bulk of the remainder being chemically combined water, and when mixed with the high-grade potash salts available will make a complete fertilizer some six times as concentrated as the average grades sold to-day.

Urea, Dicyandiamid, and Creatin from Cyanamid

It is also possible to transform cyanamid into urea, and I have made in my experimental laboratory a great deal of pure salt in a comparatively easy and simple manner.

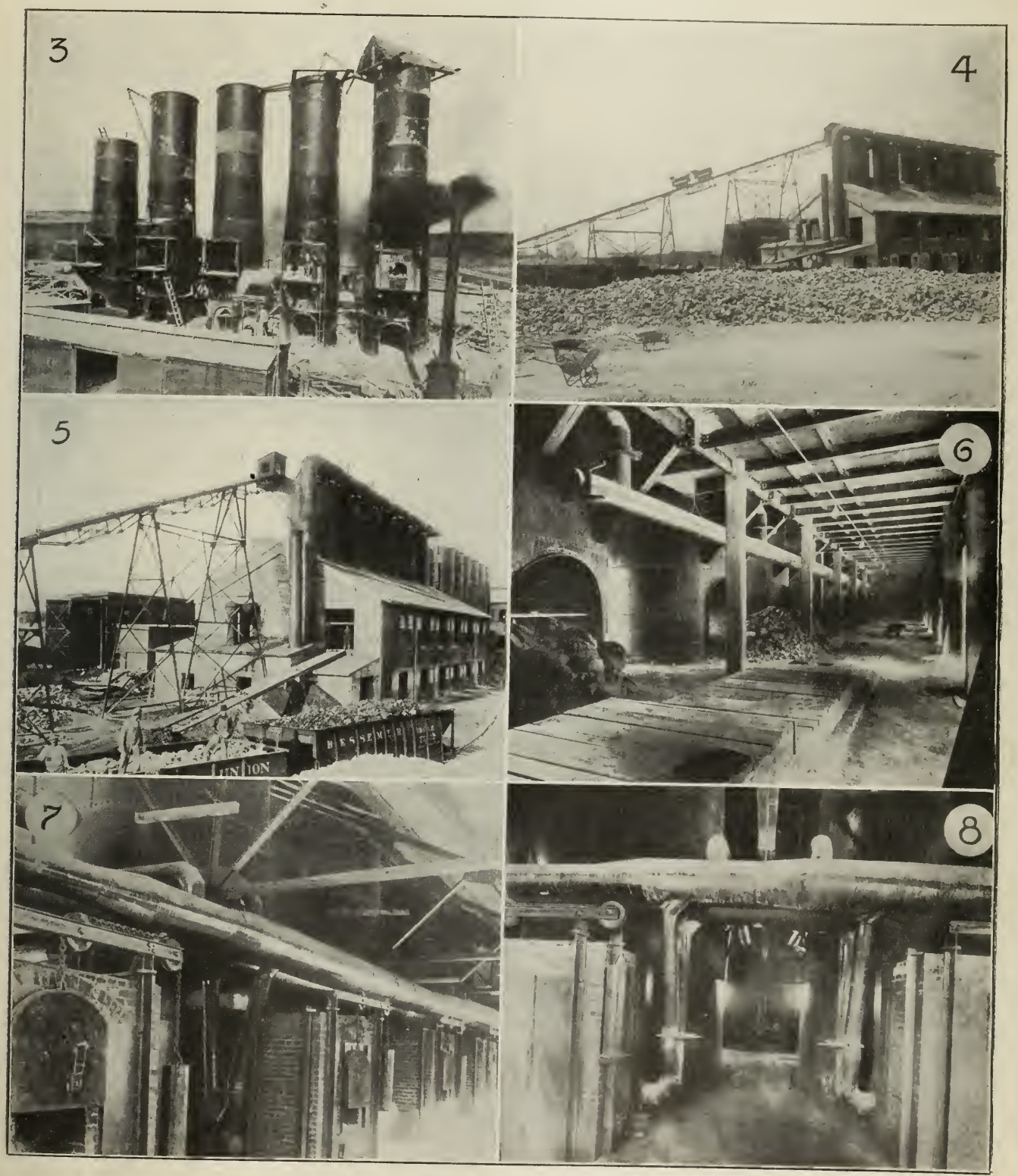
Similarly it can be converted into dicyandiamid by simple treatment with hot water. This material has been proposed for use as a deterrent in explosives, but which I think offers a much better field for transformation into the guanidines.

Such transformations of cyanamid abroad have received a great deal of attention, and there are numerous derivatives on the market. Just a few months ago I saw a sample of creatin which had been made in a chemical laboratory from cyanamid, and we feel that we in the industry are not very far from the synthetic production of foods when we can reach such a point in our chemical synthesis.

Cyanide from Cyanamid

When a special grade of cyanamid is melted down with a flux, such as common salt, it combines the free carbon present with the cyanamid radicle, forming cyanide. The resulting product of this fusion contains about 25 per cent of its weight in equivalent potassium cyanide; this crude form of cyanide dissolves very readily in water and filters rapidly from the insoluble, after which the solution is ready for metal extraction, or other uses to which cyanide in its dissolved form can be put.

Large scale experiments have been tried out in a number of the big cyanide plants scattered at various places throughout the world, and in every respect this material has shown an exactly equivalent value to the higher grade cyanides. The transformation of the cyanamid nitrogen into cyanide nitrogen is almost quantitative, and the fusion experiments can be carried out



FIGS. 3 TO 8—LIME PLANT OF AMERICAN CYANAMID COMPANY

Fig. 3: Kilns in course of construction with shells erected and fire-clay lining started. Fig. 4: Finished lime plant showing piping for induced draught and Eldred process. Fig. 5: Old lime plant with new addition, and railroad cars. Fig. 6: Lime discharge floor. Fig. 7: Firing floor with piping for Eldred process and counterweight arrangement for charging door. Fig. 8: Arrangement of the return CO_2 and hot-air pipes and damper control for Eldred process.

without difficulty and at a low cost. We have here, therefore, a crude form of cyanide which can be prepared very cheaply and which could be readily delivered to the consumer at a price approximately one-third under the present prices of the higher-grade cyanide.

Abroad this material has been made in large quantities and transformed into the pure cyanide running approximately 127 per cent potassium cyanide equivalent, but we believe that with proper propaganda work our own cyanide users would find the low-grade material quite acceptable, provided it could be delivered to them at a cost sufficiently low to enable them to perform the extra dissolving and filtering operation which it involves over the use of the present high-grade alkali cyanides.

Cyanamid for Case Hardening

Cyanamid itself forms an excellent case-hardening material, and we have prepared a number of mixtures which are in steady use at our plant for performing this operation upon various machine parts which we are using. It works extremely rapidly at very low temperatures, but we have not yet succeeded in overcoming certain fads in large scale use of this material, and it has not met with any general introduction. We found the case-hardener is more concerned with the color of his hardening powders than he is with the actual work they perform, and as the colors and odors of our cyanamid products are rather fast we have not found it interesting to us to meet some of these peculiarities of the case-hardening trade. While abroad I saw these case-hardening materials being prepared by the hundreds of tons for use in the manufacture of armament and war materials, and the small factory engaged in their production has been swamped with orders ever since its inception.

Comparison Between Different Processes for Fixation of Atmospheric Nitrogen

The arc processes have shown themselves capable of producing nitric acid or nitrates; cyanamid itself is an entirely different product, but it is quite easy to produce ammonia from it, and there has recently been evolved abroad a most successful method* of oxidizing this ammonia to nitric acid, so that in case of competition with the Birkeland-Eyde process we are not entirely limited to the fixation of nitrogen, but can furnish this nitrogen in exactly the same form that the arc processes can, and at considerably less cost.

The raw materials for cyanamid are cheap—coke, limestone, air. We use only one-fifth the electrical power that the arc processes do per unit of nitrogen fixed in the form of cyanamid, respectively ammonia, and by the addition of a very small percentage more power we can convert our cyanamid into nitric acid. We require about the same quantity of labor to fix a unit of nitrogen in cyanamid as the arc process does in nitric acid, but since there is only a small fraction more labor used to transform cyanamid nitrogen into nitric acid we do not feel this is a great handicap when one considers our smaller power consumption. On the American continent, where water power is so expensive and so scarce, this difference readily offsets the additional labor necessary to make nitric acid from cyanamid.

Further, our cyanamid is easily transported and can be changed to ammonia or nitric acid at the end of its journey at the expenditure of a very small amount of steam and labor, so that we have the additional advantage in transportability of stable raw material, and subsequent conversion at the point of direct use. These commercial transformation units are small, and can be set up to supply even small amounts of ammonia or acid in a quite cheap and efficient plant. Practically all sulphuric acid plants in Germany have installed them since nitrate has disappeared from the trade.

There is no comparison between the initial investment required for a cyanamid plant and for an arc plant if one will include power development. The cyanamid plant, per unit of nitrogen fixed, requires an investment of only about one-quarter that required by the arc process, and for a cyanamid-ammonia plant about one-half that required by the Haber process. Even the combination of the cyanamid-ammonia-nitric acid process requires an investment of only one-third to one-half that for the arc process. In each case we are assuming exactly the same quantity of fixed nitrogen in the forms above designated.

Where electrical power is expensive, as in the United States, there is no question regarding the superiority of the cyanamid process for the fixing of atmospheric nitrogen, particularly for fertilizer purposes, and we eventually hope that the future development of our nitric acid process will enable us to compete in every line of nitrogen compounds with all other competitive sources.

* * *

The Niagara Falls Plant of the American Cyanamid Co.

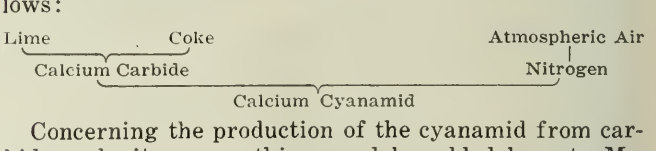
Mr. Landis illustrated his paper by a series of very interesting moving pictures, showing the most important steps in cyanamid manufacture at Niagara Falls.

As a substitute for the movies we give some representative views. As the Niagara Falls plant of the American Cyanamid Company comprises a 12-kiln lime plant, 25,000 horsepower of calcium carbide furnaces, a liquid-air plant which was the largest in the world a year ago, a gas plant of sufficient size to serve an average town of 25,000 inhabitants, a nitrogen retort plant, an ammonia refrigeration plant, a causticizing plant, a nitrification plant, a hydration plant, and innumerable crushers, mills, silos and feeding machinery, we cannot do more than give illustrations of some departments, chiefly the gas plant and the lime plant.

Fig. 1 gives a view of the works of the American Cyanamid Co. at Niagara Falls, Ontario, showing the lime plant at the extreme right, the coal gas plant at the extreme left, and the carbide and cyanamid plant in the center. A diagrammatical plan of the arrangement of the whole works is given in Fig. 2, which is reproduced from *Engineering News* of January 7, 1915.

The plant was started in 1909 with an annual output of 12,000 tons of cyanamid. The plant was enlarged in 1913 to an annual output of 32,000 tons, and in 1914 again enlarged so that the output is now 64,000 tons.

The whole operation may be concisely sketched as follows:



Concerning the production of the cyanamid from carbide and nitrogen nothing need be added here to Mr. Landis' paper.

The manufacture of calcium carbide is carried out in continuous operation in eight 20-ton, 3000-hp three-phase electric furnaces, each with three large carbon electrodes at the top. The charging platform for the furnaces is on a level with the top of the furnaces. The transformers are placed below the charging platform close to the furnaces, so as to require only very short connections between furnace and transformer.

*See, for instance, this journal, vol. 11, page 438 and 476, 1913.

Lime Plant.

The lime is burnt in the lime plant which was designed by the Improved Equipment Company of New York City, to whom we are indebted for the photographs reproduced in Figs. 2 to 8. The lime plant consists of twelve Doherty-Eldred lime kilns, equipped with the Eldred process and operated with induced draught. The first installation comprised six kilns, and six more were erected last year.

Fig. 3 shows the kilns in course of construction; the kiln shells have been erected and the fire-clay lining has been started. Fig. 4 is a view of the finished lime plant and shows the piping for induced draught and Eldred process. Fig. 5 is a view of the old lime plant with the new addition in course of erection, and shows the limestone being brought to the plant in cars. Fig. 6 is a picture of the lime discharge floor, Fig. 7 a picture of the furnace or firing floor with the piping for

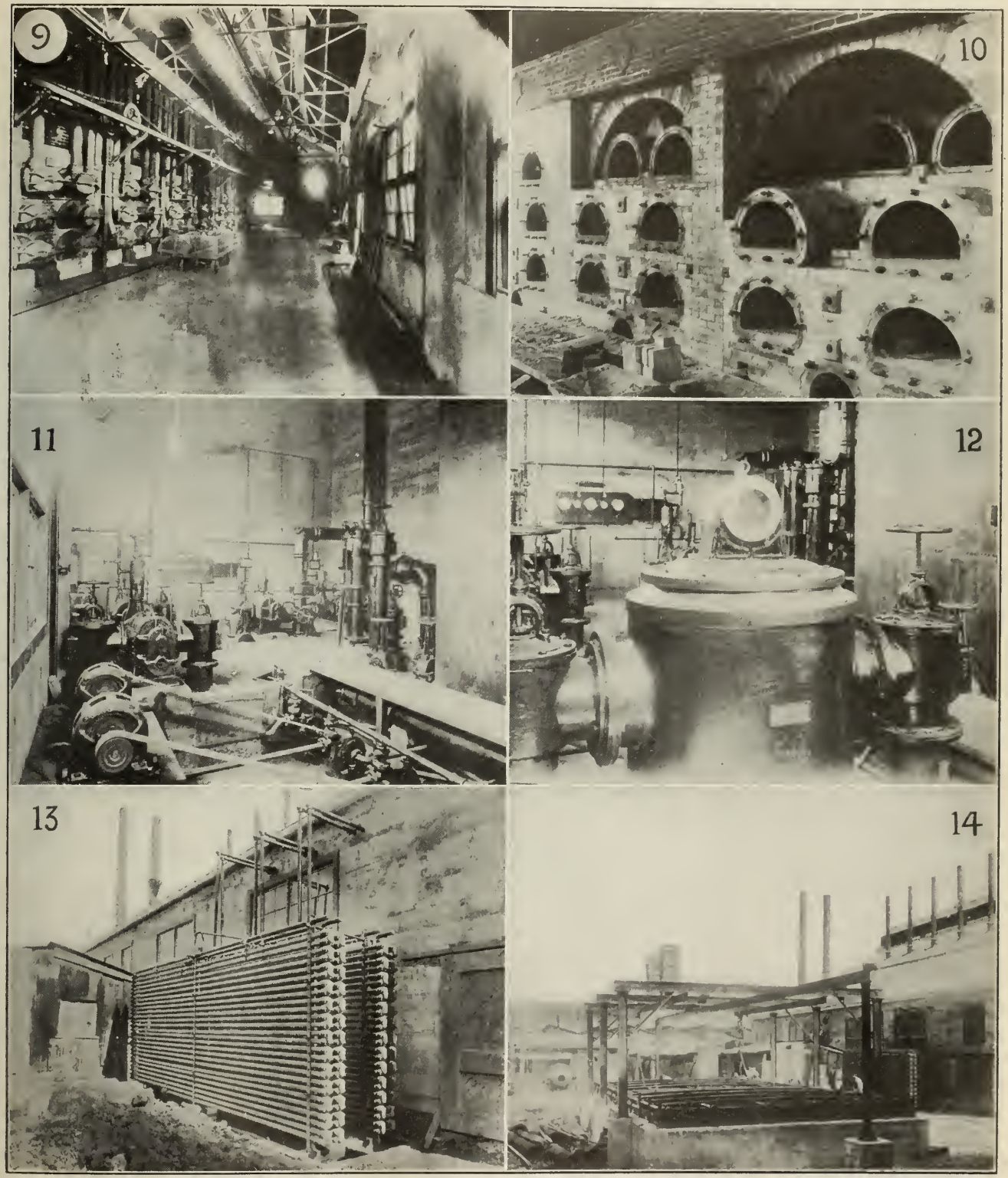


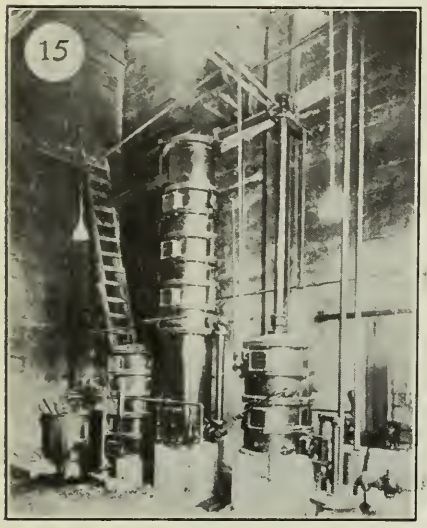
FIG. 9 TO 14—COAL GAS PLANT OF AMERICAN CYANAMID COMPANY

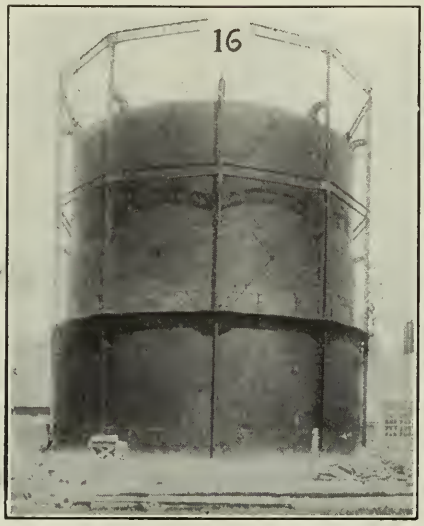
Fig. 9: Charging floor of retort house with conveyor system and coal buggy. Fig. 10: Manner of laying up the sectional silica retorts and settings. Fig. 11: Machinery room with Doherty washer cooler and centrifugal pump. Fig. 12: Rotary meter. Fig. 13: Side view of cooling coils of Doherty washer cooler. Fig. 14: End view of concrete purifying boxes.

the Eldred process and counterweight arrangement of the charging door, while Fig. 8 shows the arrangement of the return CO_2 and hot-air pipes and the damper control for the Eldred process.

The Eldred process and its applications to lime kilns was described very fully in an article by Mr. Carleton Ellis in our Vol. II, p. 495 (1904). The exhaust gas from the kilns is drawn by an exhauster from the top of the stacks and part of it is used as a "diluent" for the air in the fire boxes to get correct conditions of combustion. The balance of the exhaust gas is led to the waste stack.

The coke for the carbide manufacture is partly bought as such and the balance comes from the gas plant to be described later.





FIGS. 15 TO 17—COAL-GAS PLANT OF AMERICAN CYANAMID COMPANY

Fig. 15: Ammonia still. Fig. 16: Gas holder of 100,000 cubic feet capacity. Fig. 17: Doherty washer cooler

Nitrogen from Air.

As explained in Mr. Landis' paper the nitrogen (needed for the reaction with carbide to form cyanamid) must first be separated from the oxygen in the atmospheric air. Two different processes are being used for this purpose at Niagara.

The newer method, installed for the latest extension of the plant last year, uses liquid air produced by the Claude process. The oxygen is separated from the nitrogen by fractional distillation of the liquid air.

The older method used is the so-called copper sponge method, in which retorts filled with copper sponge are employed. When a series of these retorts is heated and air is blown through the copper sponge, the oxygen of the air combines with the copper, forming cupric oxide and leaving the nitrogen free. The flow of air is then diverted to a second series of heated retorts, also containing copper sponge, while coal gas is passed through the first series of retorts so as to reduce the cupric oxide to copper sponge. This is then used again for combining with the oxygen in a fresh amount of air and setting the nitrogen free, and so on. The process is therefore cyclic.

Coal Gas Plant

From the foregoing description it will be seen that the coal gas plant serves a double purpose. It provides coke for the carbide manufacture, and it provides the coal gas for the reduction of cupric oxide in the separation of nitrogen gas from atmospheric air.

The coal-gas plant has a capacity of 500,000 cubic feet per 24 hours. As Mr. Landis explains in his paper above, the standard coal gas process is not used; the retort benches are run very hot to produce a gas rich in hydrogen and coke low in volatile matter. They "are running at temperatures in the retorts and obtaining qualities of coke and gas that the average city gas plant would not consider as possible of attainment, and it is only after considerable experiment that we ourselves demonstrated that our theories were correct in this respect and succeeded in finding gas engineers liberal-minded enough to incorporate our ideas into a working plant."

The coal gas plant was installed by the Improved Equipment Company of New York City, to whom we are again obliged for the photographs from which the accompanying illustrations were made. There are seven benches equipped with the Doherty bench fuel economizer and sectional silica retorts and settings.

Fig. 9 shows the charging floor of the retort house with conveyor system and coal buggy, while Fig. 10 illustrates the manner of laying up the sectional silica retorts and settings. Fig. 11 is a view of the machinery room with Doherty washer cooler and centrifugal pump. Fig. 12 shows the rotary meter, Fig. 13 is a side view of the cooling coils of the Doherty washer cooler, and Fig. 14 an end view of the concrete purifying boxes showing covers.

Fig. 15 shows the ammonia still, Fig. 16 the gas holder of 100,000 cubic feet capacity, and Fig. 17 the Doherty washer cooler.

Before concluding this article, attention should be called to an admirable paper by Mr. Frank S. Washburn, president of the American Cyanamid Company, which was presented last month at a joint meeting of the American Institute of Electrical Engineers and the New York section of the American Electrochemical Society, and will come up for discussion again at the annual convention of the American Electrochemical Society at Atlantic City in April. It will be published in full in our next issue. An abstract of this paper, together with an account of another excellent paper, by Mr. Summers, on the general situation in the fixation of atmospheric nitrogen, will be found on page 241 of the present issue.

The first authentic discovery of tin in Nevada has been announced by the Mackay School of Mines. Samples from Battle Mountain proved to be stream tin of good quality.

The Formation and Decomposition of Sulphates During Roasting

BY BOYD DUDLEY, JR.

It is the purpose of the writer to present in this paper a general discussion of some of the chemical principles or laws that govern the formation and the decomposition of metal sulphates in the roasting furnace.

When a metal sulphide is heated in the presence of air to its kindling or ignition temperature, which varies with different sulphides and depends to some extent upon the grain size of the material,[1] there are formed primarily the metal oxide and sulphur dioxide,

$$MS + 1\frac{1}{2}O_2 = MO + SO_2$$

The sulphur dioxide thus formed may be carried as such from the furnace by the excess air, or it may be oxidized to sulphur trioxide,

$$2SO_2 + O_2 = 2SO_3,$$

the oxygen required for this process being derived from the atmosphere of the furnace or possibly from certain metal oxides that are capable of being reduced to lower states of oxidation.

Most metal oxides will, under proper conditions, unite with sulphur trioxide to form the metal sulphate,

$$MO + SO_3 = MSO_4.$$

In some cases the normal sulphate does not represent the only possibility since basic sulphates may be produced,

$$aMO + bSO_3 = aMO.bSO_3.$$

Wherein a and b are small whole numbers, the ratio of a to b being greater than in the case of the normal sulphate. Basic sulphates may, of course, be converted into the normal compounds and the reverse, under proper conditions.

The formation of sulphates according to this series of reactions is of frequent occurrence in the roasting of sulphide ores. Sometimes it is desired to maintain conditions in the furnace that will produce the greatest possible amount of some particular sulphate, for example in the sulphatizing roast of copper ore preparatory to leaching. But when the object of the roast is to eliminate sulphur as completely as possible, the formation of sulphates is undesirable, because in order to secure the desired result they must be subsequently decomposed. From the foregoing it would appear that the subject of sulphate formation and decomposition is one of considerable metallurgical interest, and that an analysis of the laws and principles and facts involved may prove of value.

I. Chemical Equilibrium Conditions

Consider first the general equation that has been used to represent the formation of sulphates,

$$MO + SO_3 \rightleftarrows MSO_4.$$

Such reactions are in general reversible as the equation indicates. Consequently it is possible to dissociate a sulphate into metal oxide and sulphur trioxide as well as to form it from these constituents, the direction in which the reaction proceeds being determined by the conditions imposed. Likewise the formation of basic sulphates from metal oxides and sulphur trioxide and their formation by the dissociation of normal sulphates are reversible reactions.

In addition to the simple dissociation of sulphates it is sometimes possible to effect decomposition by heating to sufficiently high temperatures with silica, ferric oxide, and other substances, forming thereby silicates, ferrites, etc. An example of the practical application of this is the decomposition of lead sulphate by silica in slag roasting. Such reactions as the latter, however, are practically irreversible under roasting conditions and, therefore, do not possess so great a theoretical interest as do the others that have been mentioned.

Viewed from the standpoint of the phase rule the system composed of a metal sulphate, the oxide, and sulphur trioxide is monovariant, i. e., at a given temperature a definite concentration of sulphur trioxide must be maintained in the gas phase in contact with a metal sulphate and oxide in order to maintain equilibrium. In other words the dissociation tension of a sulphate with respect to sulphur trioxide is constant at constant temperature.

It is not possible with the aid of the phase rule to calculate the values of the equilibrium concentrations or dissociation pressures that correspond to various temperatures; they must be determined experimentally in the case of each compound. However, experiment has shown that the dissociation of a sulphate, whether into oxide or only into a basic sulphate, to be an endothermic reaction. From this fact it is possible to state, with the aid of the principle of Le Chatelier,[2] that the dissociation tension of a sulphate increases with increasing temperature. It can also be shown that the basic sulphate resulting from the dissociation of a normal sulphate possesses at given temperatures lower dissociation tensions than does the compound from which it is formed. There is, of course, one temperature, that of the co-existence of the two sulphates and the oxide, at which the dissociation tensions of the two are equal.

It follows from the above that, if a metal sulphate is held at constant temperature in a space wherein the sulphur trioxide concentration is less than the equilibrium concentration corresponding to the prevailing temperature, the sulphate will undergo dissociation. If the sulphur trioxide concentration is kept constant, the dissociation will continue either until the sulphate is completely converted into oxide or is converted into a basic compound, the dissociation tension of which is less than the prevailing partial pressure of sulphur trioxide.

In case the formation of a basic sulphate is possible and the normal sulphate is held at constant temperature in a space containing a lower sulphur trioxide concentration than corresponds to the dissociation tension of the basic sulphate, the normal compound will first dissociate until it has been converted into the basic sulphate, which in turn will dissociate with the production of perhaps a second basic compound, or more commonly the metal oxide. On the other hand, if a metal oxide is held at constant temperature in a space wherein is maintained a higher concentration of sulphur trioxide than corresponds to the dissociation tension of the sulphate at the prevailing temperature, the oxide will be sulphatized, the normal sulphate being produced directly from the oxide only when basic sulphates do not exist. When basic sulphates are possible, the process of forming the normal compound will be the reverse of the process of its decomposition, as described above.

The view may be maintained that such considerations as have been outlined above are of no practical value in a study of the reactions of roasting, because in the roasting furnace the gases are drawn off continuously and with such rapidity that the sulphur trioxide concentration is maintained at an extremely low figure. Numerous analyses of roasting furnace gases appear to support this contention. The fact remains, however, that sulphates are formed during the roasting of sulphide ores, and that in many cases they are subsequently decomposed. In view of this, what are the reactions and what considerations do apply, if the foregoing do not?

The fallacy of such arguments doubtless lies in the

[1] Hofman, General Metallurgy, p. 403, 1913. Friedrich, Metallurgie, VI, 170, 1909.

[2] Nernst, Theoretical Chemistry, Translation 6th Ger. Ed., p. 676.

assumption that the concentration of sulphur trioxide in the furnace gas as a whole is the same as that in the gas immediately in contact with the roasting ore. Such is not the case. The concentrations of sulphur oxides in the gas in contact with even the topmost layer of grains in a roasting bed of ore are probably higher than in the furnace gas as a whole, owing to absorption and to the rate of diffusion of these compounds through the film of gas in contact with the solids. Laying aside this point for the present, it cannot be denied that the gas in the interstices of the ore bed is usually much richer in sulphur oxides and poorer in oxygen than is the furnace gas or the flue gas. Otherwise rabbling or stirring the roasting ore would serve no useful purpose, while in fact rabbling does accelerate the process of roasting by exposing new particles of ore to the direct action of the furnace gas, by liberating the sulphur oxides from the interstices of the ore bed, and by thus increasing the oxygen concentration within these spaces.

Inasmuch as it is the sulphur trioxide concentration in the gas in close contact with the roasting ore and not its concentration at some distance away that constitutes a determining factor in the formation and dissociation of metal sulphates, it becomes evident that, in the consideration of these reactions, attention must be directed toward the composition of the intersticial gas and toward the reactions occurring in such spaces rather than toward the composition of the furnace gas as a whole. But it must be remembered that thoroughness and rapidity of stirring or rabbling together with the depth of the bed of ore being worked constitute important factors in determining the average differences in composition that may exist between the intersticial gas and the furnace gas.

The formation and decomposition of a metal sulphate according to the reversible processes described in a preceding paragraph is in many respects similar to the formation and dissociation of calcium carbonate, according to the reaction,

$$CaCO_3 = CaO + CO_2.$$

In the case of the sulphate the process is not quite so simple and does not lend itself so readily to investigation, because of the complication arising from the dissociation of the sulphur trioxide according to the reaction,

$$2SO_3 \rightleftarrows 2SO_2 + O_2.$$

The reaction is reversible as is shown by the equation. It is endothermic when proceeding from left to right, which indicates that increasing temperature produces a change in the equilibrium that causes, under given conditions, a more complete dissociation of the sulphur trioxide.

Since at the elevated temperatures of the roasting furnace the reactions of sulphate formation and decomposition occur in company with the reversible reaction between the sulphur oxides and oxygen, the two processes are inseparably linked, and the former cannot be well understood without a clear understanding of the latter. Therefore a discussion of the sulphur trioxide, sulphur dioxide, and oxygen equilibrium will be presented.

The most useful information in regard to this reaction is obtained from the law of chemical mass action, which states that at a definite temperature equilibrium among the three gases is defined by the equation,

$$\frac{C^2_{SO_2} C_{O_2}}{C^2_{SO_3}} = K.$$

Wherein C_{SO_2}, C_{O_2} and C_{SO_3} are the concentrations of the gases designated by the subscripts, and K is the reaction constant. The value of K, while constant for each temperature, increases with increasing temperature. This, it will be noted, indicates under given conditions a decrease in the concentration of sulphur trioxide in the equilibrium mixture as the temperature increases.

The determination of the values of the equilibrium constant of this reaction has been the object of a number of investigations,[3] and, while the results of the various observers are somewhat conflicting, it appears that those of Bodenstein and Pohl are perhaps the most reliable. Accordingly their figures will be quoted, and used in certain calculations that are to follow. Table I contains the values of K determined by these investigators.

Table I—Equilibrium Constants of SO_3, SO_2, and O_2, Reaction at Various Temperatures

Temp. C.	K	Log K
528°	1.55×10^{-5}	−4.810
579	7.55×10^{-5}	−4.126
627	3.16×10^{-4}	−3.500
680	1.12×10^{-3}	−2.914
727	3.54×10^{-3}	−2.451
789	1.26×10^{-2}	−1.900
832	2.80×10^{-2}	−1.552
879	8.16×10^{-2}	−1.089

The values of K given in the above table apply to the reaction,

$$2SO_3 \rightleftarrows 2SO_2 + O_2.$$

and, in order to use these values in calculations, it is necessary to use the concentrations of the gases expressed in gram molecules per liter. It happens that calculations of the kind that are to be made are more conveniently performed and the results are more readily interpreted, when the partial pressures of the gases are used in place of the concentrations. Also it will be more convenient to write the equation in the form,

$$SO_2 + \tfrac{1}{2}O_2 \rightleftarrows SO_3.$$

The conventional mass action equation for the reaction, when so expressed and when the partial pressures of the gases are being considered, is

$$\frac{p_{SO_3}}{p_{SO_2}\sqrt{p_{O_2}}} = K_1.$$

Wherein K_1 is the mass action constant, the subscript being employed to distinguish it from the K used above.

Calculation of the values of K_1 from those of K is accomplished with the aid of the gas law equation,

$$pv = NRT.$$

Wherein p is the pressure of the gas under consideration; v is its volume; N is the number of gram molecules or mols involved; R is the gas constant; and T is the absolute temperature.

Now the concentration, C, of any gas expressed in mols per liter is N/v, N being the number of mols involved and v being the volume of the gas in liters under the assumed conditions.

Hence the gas-law equation may be expressed in the form,

$$p = CRT, \text{ or } C = \frac{p}{RT}.$$

Substituting for the concentrations, C_{SO_2}, C_{O_2} and C_{SO_3}, in the first mass-law equation their equivalents, p_{SO_2}/RT, etc., there is obtained the equation,

$$\frac{p^2_{SO_2} p_{O_2}}{p^2_{SO_3}} \cdot \frac{1}{RT} = K, \text{ or } \frac{p^2_{SO_2} p_{O_2}}{p^2_{SO_3}} = RTK.$$

Extracting the square root of the last expression and inverting both sides gives

$$\frac{p_{SO_3}}{p_{SO_2} p^{\frac{1}{2}}_{O_2}} = \frac{1}{(RTK)^{\frac{1}{2}}}.$$

[3] Knietsch, *Berichte d. Deut. Chem. Ges.*, XXIV, 4069, 1901. Mineral Industry, X, 622, 1901. Bodländer and Koppen, *Zeit. für Elektrochem.*, IX, 787, 1903. Bodenstein and Pohl, *Zeit. für Elektrochem.*, XI, 373, 1905. Von Lucas, *Zeit. für Elektrochem.*, XI, 457, 1905.

Combining this with the second mass-law equation involving K_1 yields the relation,

$$K_1 = \frac{1}{(RTK)^{\frac{1}{2}}}.$$

The value of R to be used depends upon the unit in which it is desired to express the gas pressures. If these are to be expressed in millimeters of mercury, $R = 62.4$, and the expression relating K and K_1 becomes

$$K = \frac{1}{(62.4\ TK)^{\frac{1}{2}}}.$$

The temperature, T, is expressed in degrees, C, on the absolute scale.

With the aid of the above equation, Table II, containing values of K_1 and log K_1, has been prepared. Plotting

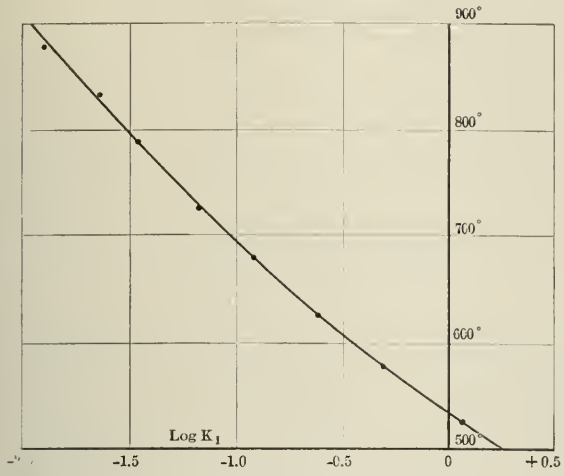


FIG. 1—VARIATION OF LOG K_1 WITH TEMPERATURE

these values of log K_1 against their corresponding temperatures gives Fig. 1. From this the values of log K_1 and K_1 at intervals of 50 deg., beginning at 500 deg., are taken to form Table III.

TABLE II—VALUES OF K_1 AND LOG K_1 AT VARIOUS TEMPERATURES

Temp. C.	K_1	log K_1
528°	1.14	0.057
579	4.96×10^{-1}	−0.304
627	2.39×10^{-1}	−0.622
680	1.22×10^{-1}	−0.913
727	6.70×10^{-2}	−1.174
789	3.46×10^{-2}	−1.461
832	2.27×10^{-2}	−1.644
879	1.29×10^{-2}	−1.890

TABLE III—VALUES OF K_1 AND log K_1 AT 50° INTERVALS BEGINNING WITH 500°

Temp. C.	K_1	log K_1
500°	1.78	0.250
550	7.95×10^{-1}	−0.100
600	3.55×10^{-1}	−0.450
650	1.78×10^{-1}	−0.750
700	9.23×10^{-2}	−1.035
750	5.13×10^{-2}	−1.290
800	3.06×10^{-2}	−1.515
850	1.82×10^{-2}	−1.740
900	1.10×10^{-2}	−1.960

By substituting the proper value of K_1 in the mass-law equation and by using this in connection with the chemical equation, it is possible to calculate with reasonable certainty the composition of the equilibrium mixture that will result from bringing together specified amounts of sulphur trioxide, sulphur dioxide, and oxygen at a definite temperature and pressure.

A special case that, as will be subsequently shown, is of particular interest in connection with the formation and decomposition of sulphates, is when sulphur trioxide alone is decomposed, or when sulphur trioxide is formed by bringing together sulphur dioxide and oxygen in the proportions of two mols of the former to one of the latter. Starting with pure sulphur trioxide it is seen from the chemical equation that at equilibrium as many mols of sulphur dioxide have been formed as of sulphur trioxide decomposed, and half as many mols of oxygen have been produced as of sulphur dioxide. Consequently, in the equilibrium mixture the conditions are represented by the following equations:

$$\frac{p_{SO_3}}{p_{SO_2}p^{\frac{1}{2}}_{O_2}} = K_1$$

$$p_{SO_2} = 2p_{O_2}$$

$$p_{SO_3} + p_{SO_2} + p_{O_2} = p_t.$$

Wherein p_{SO_3}, p_{SO_2} and p_{O_2} are the partial pressures of sulphur trioxide, sulphur dioxide and oxygen, respectively; and p_t is the total pressure of these three gases. Eliminating p_{SO_2} and p_{O_2} from these equations yields a relation involving the partial pressure of sulphur trioxide in terms of K_1 and the total pressure, p_t.

$$\frac{p_{SO_3}}{(p_t - p_{SO_3})^{3/2}} = 0.385\ K_1.$$

This equation is useful in calculating the partial pressure of sulphur trioxide in the equilibrium mixture resulting from the dissociation of this compound under given conditions of temperature and total pressure. The solution of the equation for p_{SO_3} is most readily accomplished by trial.

The composition of equilibrium mixtures resulting

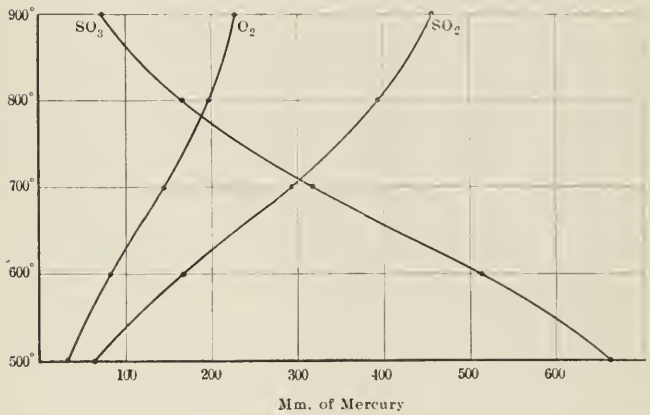


FIG. 2—COMPOSITION OF SO_3, SO_2 AND O_2 EQUILIBRIUM MIXTURES RESULTING FROM DISSOCIATION OF SO_3 AT ATMOSPHERIC PRESSURE

from the dissociation of sulphur trioxide at various temperatures under a pressure of one atmosphere (760 mm. of mercury) have been calculated. They are given in Table IV, and are shown graphically in Fig. 2.

TABLE IV—COMPOSITION OF EQUILIBRIUM MIXTURES OF SO_3, SO_2, AND O_2 EXPRESSED IN MM. OF MERCURY, THE TOTAL PRESSURE BEING 760 MM.

Temp. C.	P_{SO_3}	P_{SO_2}	P_{O_2}	$\frac{P_{SO_3}}{P_{SO_2}}$
500°	663	65	32	10.2
600	517	162	81	3.19
700	322	292	146	1.11
800	170	393	197	0.433
900	75	457	228	0.164

An important point to be considered in connection with the reaction under discussion is that of reaction velocity, which determines the length of time required for a mixture of the gases to react and produce equilibrium conditions. The time required depends, of course, upon the original concentrations of the reactants and upon the temperature. The effect of temperature in this case, as in most others of its kind, is to accel-

erate the reaction rate at the higher temperatures. But aside from these factors there is another of even greater importance, namely, the effect of catalysts upon the reaction rate. It has been found that under given conditions of temperature, initial gas mixture, etc., the reaction will proceed to equilibrium conditions at a greatly accelerated rate when the gases are brought into contact with such substances as platinized asbestos, and that various metal oxides, notably ferric oxide, affect the reaction velocity in a similar manner but to a lesser degree.[4] The catalyst does not alter the conditions of equilibrium, these being determined by the temperature and the partial pressures of the reacting substances; and in general the catalyst has an equal effect upon the reaction velocity, whether the direction of the reaction happens to be toward the formation of sulphur trioxide or toward its decomposition.

To return to the question of the metal sulphates, numerous investigations have been conducted to determine the conditions under which the common sulphates are formed and decomposed in the roasting furnace. An interesting and instructive piece of work is that of Wöhler, Pluddemann and Wöhler,[5] who determined the equilibrium conditions of several sulphates over considerable ranges of temperature. Their method consisted of heating the sulphate in an evacuated tube at constant temperature and measuring with a mercury manometer the maximum pressure of the gases evolved. Platinum sponge was placed above the sulphate to insure the rapid attainment of equilibrium conditions within the heated space. Hence the pressure measured was that due to the equilibrium mixture resulting from the dissociation of the sulphur trioxide evolved by the sulphate. The partial pressure of the sulphur trioxide in this mixture represents the dissociation tension of the sulphate at the prevailing temperature. The total pressures of the sulphur oxides and oxygen at various temperatures above the sulphates of metallurgical interest that were studied in the Wöhler-Pluddemann experiments are collected in Table V. These data have been plotted to scale in Fig. 3.

Table V—Total Pressures of SO_3, SO_2, and O_2 Above Sulphates

$Fe_2(SO_4)_3$		$Al_2(SO_4)_3$		$CuSO_4$		$2CuO.SO_3$		$ZnSO_4$	
Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.	Temp. Deg. C.	Press. Mm.
553	23	572	28	546	43	600	62	675	5
570	33	621	51	588	55	653	98	690	6
592	45	681	120	615	70	686	123	720	24
614	70	702	180	642	98	705	139	750	61
634	113	720	261	665	130	728	173	775	112
650	149	731	356	700	233	745	209	800	189
660	182	742	480	714	324	775	298	.....	.....
680	286	748	692	725	460	805	542	.....	.....
690	401	.....	.....	731	647	.....	.....	.....	.....
699	560	.....	.....	.....	.....	.....	.....	.....	.....
707	715	.....	.....	.....	.....	.....	.....	.....	.....

From the foregoing figures the equilibrium pressures of sulphur trioxide corresponding to various temperatures may be calculated for each of the sulphates listed by means of the equation,

$$\frac{p_{so_3}}{(p_t - p_{so_3})^{3/2}} = 0.385\, K_1.$$

For example, at 650 deg. the total equilibrium pressure of the sulphur oxides and oxygen above copper sulphate is seen to be 105 mm. See Fig. 3. Substituting 105 for p_t in the above equation and substituting for K_1 its value as given in Table III yields the relation,

$$\frac{p_{so_3}}{(105 - p_{so_3})^{3/2}} = 0.385 \times 0.178.$$

Solving this equation by trial shows p_{so_3} to be 37.7 mm. By this method the equilibrium pressures of sulphur trioxide above the different sulphates have been calculated for various temperatures. The calculated values are given in Table VI, and they have been plotted against the corresponding temperatures in Fig. 4.

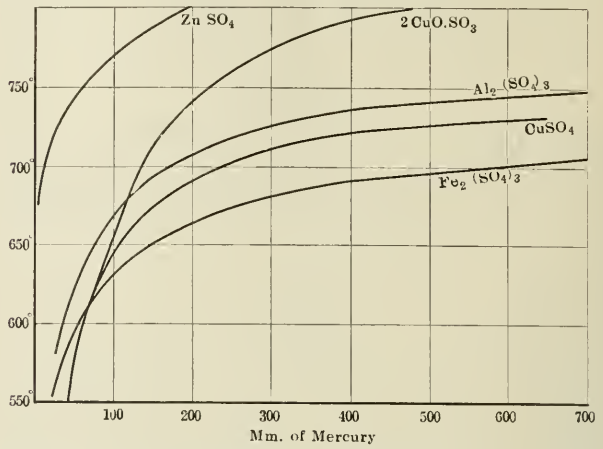


FIG. 3—TOTAL EQUILIBRIUM PRESSURES OF SO_3, SO_2 AND O_2 ABOVE VARIOUS SULPHATES

There are thus provided in convenient form the known facts concerning the equilibrium of a few of the metal sulphates and oxides with sulphur trioxide. It is unfortunate indeed that other sulphates have not been studied in a similar manner, but the data thus provided are useful in indicating the general relationship between temperature and the pressures of sulphur trioxide necessary to effect the formation of sulphates or to allow their decomposition.

Table VI—Dissociation Tensions of Sulphates at Various Temperatures, Expressed in Mm. of Mercury

Temp. Deg. C.	$Fe_2(SO_4)_3$	$CuSO_4$	$Al_2(SO_4)_3$	$2CuO.SO_3$	$ZnSO_4$
550	9.8	25.5	9.8	.....	.....
600	22.8	28.7	16.0	27.6	.....
650	58.0	37.7	25.8	33.0	.....
675	94.0	50.5	34.0	.....	0.5
700	219.	71.0	50.0	36.0	0.8
725	.....	148.	82.0	39.0	.....
750	.....	.....	.....	46.0	7.5
775	.....	.....	.....	.....	14.5
800	.....	.....	.....	85 0	24.0

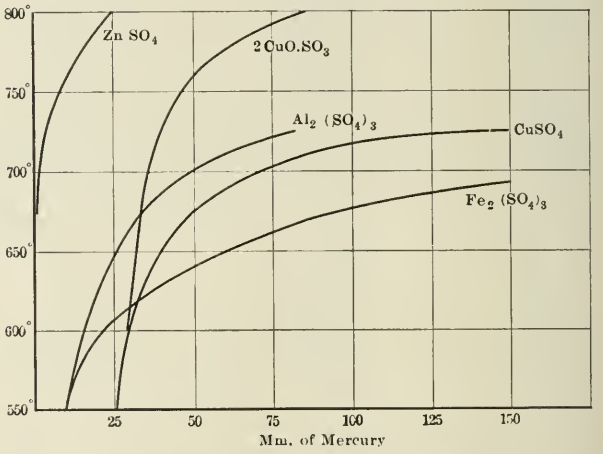


FIG. 4—DISSOCIATION TENSIONS OF VARIOUS SULPHATES WITH RESPECT TO SO_3

In general, the shape of each curve shows at first a slow increase of dissociation tension as the temperature increases. Then the increase in dissociation tension

[4] Knietsch, loc. cit.
[5] *Ber. der Deut. Chem. Ges.*, XLI, pt. 1, p. 703, 1908.

with temperature becomes more marked, and finally a comparatively slight change in temperature produces a very great change in the dissociation tension. The question of the order of decomposition of a mixture of metal sulphates is seen to depend somewhat upon the sulphur trioxide pressure in contact with them, the order at low pressures being in some cases reversed from that at higher pressures, as is shown by the crossing of the dissociation tension lines on the diagram, Fig. 4.

The properties of ferric sulphate, as shown by the curve representing its dissociation tension, deserve special mention. It will be noted that the dissociation tension of this compound is low at the lower temperatures shown on the diagram, but increases more rapidly with increasing temperature than is the case with the other sulphates shown. Since in the roasting furnace pyrite is one of the first sulphides to be ignited and oxydized, ferric oxide or the magnetic oxide of iron is produced at comparatively low temperatures. Owing to the low dissociation tension of ferric sulphate at low temperatures, it is to be expected under the circumstances that this sulphate will be the first to form. With increasing temperature, however, the dissociation tension of the ferric sulphate increases much more rapidly than that of the other sulphates. Consequently, although it may be the first to be formed, the ferric sulphate will in general suffer decomposition at lower temperatures than the other sulphates.

In viewing the subject of sulphate formation and decomposition from the standpoint of the equilibrium conditions of the reactions it must be remembered that it is very difficult, if not impossible, to predict or even to determine the magnitude of the sulphur trioxide concentration in contact with the ore at any time. This much, however, can be said: The concentrations of the sulphur oxides in the gas in immediate contact with the ore and in the interstices of the ore bed are greater than is shown by the analysis of the furnace gas as a whole. Also the composition of the gas in the interstices approaches that of the furnace gas as the depth of ore bed decreases and as the rapidity of rabbling increases.

From the foregoing discussion it follows that the formation of sulphates in the roasting furnace is promoted by low temperature, thick beds of ore, and slow rabbling; and that the reverse conditions will in general prevent the formation of sulphates or at least assist in their decomposition once they are formed. In particular it should be noted that a sulphate does not have a definite temperature of formation or of decomposition any more than water has a definite boiling point, the one being as dependent upon the sulphur trioxide concentration in the space surrounding the sulphate as the other is dependent upon the atmospheric pressure above the water.

Another important and useful investigation of the properties of the metal sulphates is that of Hofman and Wanjukow.[7] In their experiments a small amount of the sulphate contained in a porcelain boat was introduced into the horizontal tube of an electrically heated furnace, through which was passed a current of dry air. The temperature of the furnace and its contents was gradually raised, and observations were made to determine the temperature at which the sulphate begins to dissociate. In this manner the sulphate is subjected to conditions that resemble to a certain extent those obtaining in the roasting furnace.

Since in these experiments only small amounts of the sulphate (usually 0.3 g. of the crystalline salt) were worked with, the depth of the layer of sulphate in the boat was slight. With a fairly rapid current of air through the tube the partial pressure of the sulphur trioxide in contact with the surface grains of the sulphate was maintained at a low figure; though the same cannot be said of the conditions surrounding the grains of the lower layers. It is to be expected, however, that under the conditions described signs of decomposition of the sulphates will become evident at temperatures corresponding to low dissociation tensions. That this is in general the case may be seen by comparing the figures of Table VII with the curves of Fig. 4.

TABLE VII—DESULPHATIZATION OF ANHYDROUS METAL SULPHATES—HOFMAN AND WANJUKOW

Metallic Sulphates	Temperature of Beginning of Decomposition, Degrees C.	Temperature of Energetic Decomposition, Degrees C.	Products of Decomposition	Remarks
$FeSO_4$	167	480	$Fe_2O_3.2SO_3$	Yellow-brown
$Fe_2O_3.2SO_3$	492	560	Fe_2O_3	Red
$Bi_2(SO_4)_3$	570	639	$5Bi_2O_3.4(SO_4)_3$	White
$Al_2(SO_4)_3$	590	639	Al_2O_3	White
$PbSO_4$	637	705	$6PbO.5SO_3$	White
$CuSO_4$	653	670	$2CuO.SO_3$	Orange-color
$MnSO_4$	699	790	Mn_3O_4	Dark red to black
$ZnSO_4$	702	720	$3ZnO.2SO_3$	White, cold and not.
$2CuO.SO_3$	702	736	CuO	Black
$NiSO_4$	702	764	NiO	Brownish green
$CoSO_4$	720	770	CoO	Brown to black [1]
$3ZnO.2SO_3$	755	767	ZnO	Hot yellow, cold white
$CdSO_4$	827	846	$5CdO.SO_3$	White
$5Bi_2O_3.4(SO_3)_3$	870	890	Bi_2O_5(?)	Yellow
$5CdO.SO_3$	878	890	CdO	Black
$MgSO_4$	890	972	MgO	White
Ag_2SO_4	917	925	Ag	Silver white
$6PbO.5SO_3$	952	962	$2PbO.SO_3$ (?)	White to yellow
$CaSO_4$	1,200		CaO	White
$BaSO_4$	1,510		BaO	White

In determining the temperatures specified above the investigators obtained evidence of decomposition in the following manner: The furnace containing the sulphate under investigation was heated slowly by passing an electric current of constant strength through the resistance coil. Data for a temperature-time heating curve of the furnace were obtained by making temperature observations at definite time intervals, the position of the junction of the thermo couple, with which the observations were made, being near the surface of the sulphate contained in the boat. Since the dissociation of a sulphate is an endothermic reaction, the curve plotted from such data will show a jog when the rate of decomposition of the compound becomes sufficient to make evident the thermal effect in this manner. Also the gases issuing from the furnace tube were tested by suitable indicators for sulphur trioxide and sulphur dioxide.

The figures given in Table VII represent, therefore, simply the temperatures at which decomposition under the existing conditions could be identified by the means employed. In fact, in many cases, due to slight evidences of dissociation at lower temperatures than those specified, considerable latitude was left to the observer in his decision as to just what temperature corresponds to the beginning of decomposition at a practically important rate. Consequently the figures given, while of great value because they represent temperatures at which the various sulphates are decomposed at a fairly uniform rate under certain conditions determined by the method of the experiments, do not necessarily represent the minimum temperatures at which the sulphates undergo decomposition. Nor do these figures necessarily represent the temperatures at which the respective sulphates are decomposed in the roasting furnace, the temperature of decomposition being in each case a variable as has been explained in a preceding paragraph.

To summarize, it may be said that the decomposition temperatures thus determined are dependent to a great extent upon the rates of decomposition of the different sulphates under the conditions existing at the time of the experiments. This brings up the question of reaction velocity in heterogeneous systems and the factors and conditions upon which it depends. These are of im-

[7] T. A. I. M. E., XLIII, 523, 1913.

portance, because, from a practical viewpoint, it is of little use to know that a reaction may take place but at so slow a rate as to render its effects imperceptible.

Metallurgical Smoke

The U. S. Bureau of Mines has recently issued *Bulletin* 84, by Charles H. Fulton, setting forth in "plain and simple English" the facts regarding metallurgical smoke and its treatment. The pamphlet contains much valuable information, including data on operating plants and illustrations of various methods for controlling smoke production.

As showing the tremendous volume of smoke that may be produced at a large smelter, the following data

Table I—Part of Flue System

Constituent	Flue from roasting furnaces	Flue from blast furnaces	Flue from converters	Flue from reverberatory furnaces	Flue at base of stack
Sulphur dioxide	2.545	1.274	2.845	4,423	1.164
Sulphur trioxide	0.275	0.086	0.0505	0.0044	0.0395
Carbon dicxide.	0.1136	6.493	0.2084	5.242	2.748
Water vapor...	2.784	3.490	1.061	3.869	2.834
Arsenic trioxide	0.0073	0.0091	0.00073	0.0156	0.00465
Oxygen	14.02	10.18	12.04	10.37	11.88
Nitrogen	81.18	78.13	83.64	79.57	80.73
Carbon monoxide	None	None	None	Trace	None
Total	100.90	99.70	99.80	99.50	99.40

are given on the Anaconda smelter. The stack discharges 1,341,000,000 cu. ft. of smoke per 24 hours, containing about 1.734 per cent by volume of sulphur dioxide, equivalent to 3427 tons of sulphuric acid.

The composition of gases from a typical Western copper smelter, in percentage of volume at 0 deg. Cent. and 760 mm pressure, is given as follows:

The dust and fume losses at smelting plants reaches a magnitude that would not be suspected unless thoroughly investigated. Thus at Great Falls with the old flue system in use it was demonstrated that there was a daily loss in dust of 3775 lb. copper, 106 oz. silver and 0.71 oz. gold. With the new flue system this was reduced to 347 lb. copper, 28.5 oz. silver and 0.2 oz. gold. The saving effected was $372 a day by a flue system that cost $1,100,000. At the Copper Queen plant there was a daily loss of copper in dust amounting to between 6000 and 18,000 lb. copper, depending on the number of furnaces in use.

The *Bulletin* discusses methods of recovering fume and dust from smelter smoke, and describes and illustrates different flue systems, bag houses and electrical precipitation apparatus. It also covers the manufacture of sulphuric acid from smelter gases and describes the work at the Tennessee smelters. The Hall and Thiogen processes for recovering sulphur from roasting ores are briefly described.

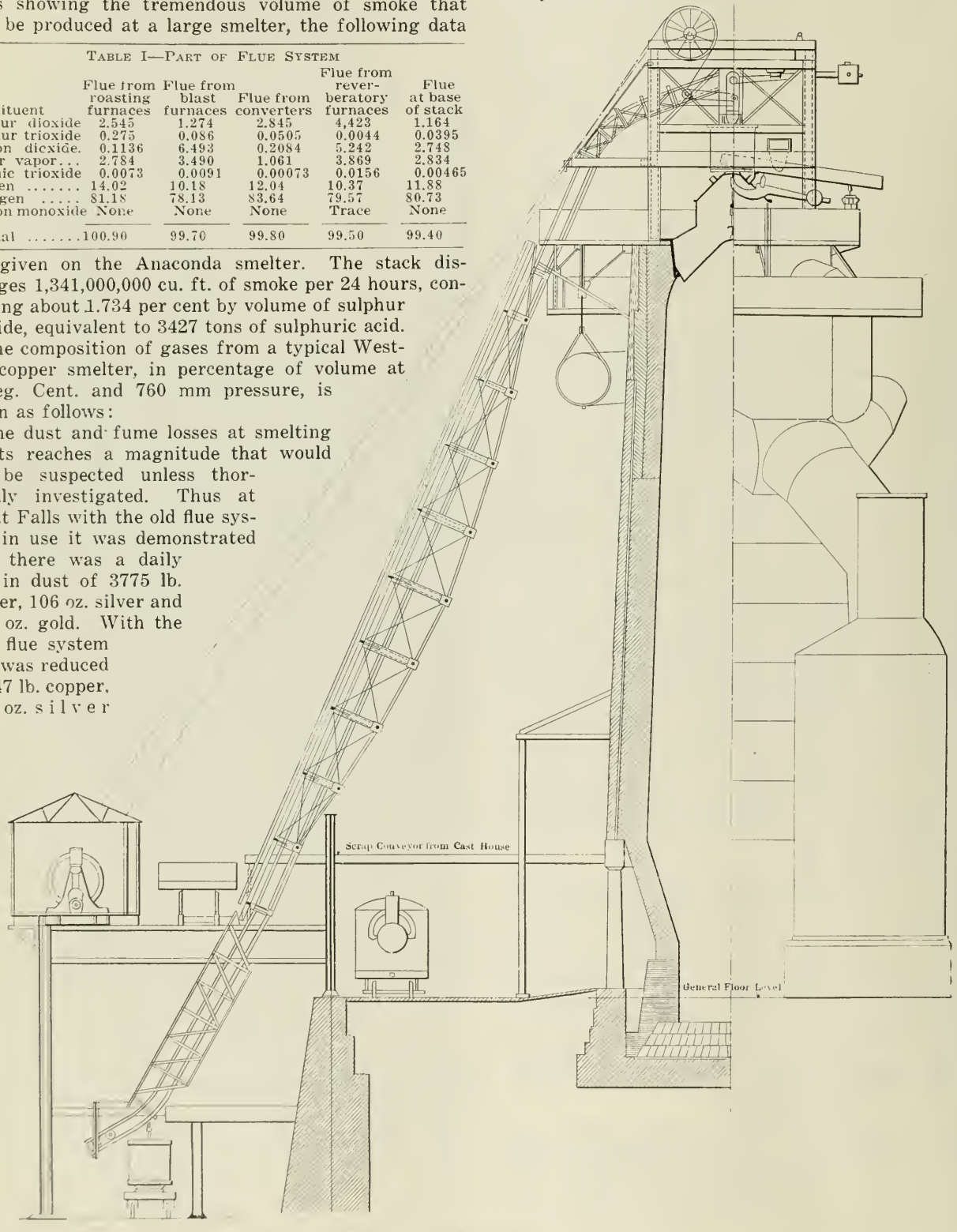


FIG. 22—GENERAL ARRANGEMENT OF NEELAND TOP

Filling the Blast Furnace

BY J. E. JOHNSON, JR.

(*Concluded from page* 173)

The Bucket System of Distribution

When the Duquesne furnaces were designed, as I have previously explained, practically all the traditions of blast furnace design were discarded and the engineers struck out on lines boldly new in almost every direction. This was true in regard to the filling system which was invented for that plant by M. A. Neeland, then chief engineer of those works.

When the plans for the plant were started there were only two mechanically filled furnaces running, one with the Brown top at Sharon, previously mentioned, and one with the upper hopper closed by an orange peel at the Lucy furnaces which their superintendent recommended be *not* adopted.

A set of drawings for a skip-filling system had been made, but when Mr. Rotoff (since deceased) came to the plant to be superintendent of the furnaces which it was proposed to build, he rejected this design absolutely as he had had experience with some very unsuccessful skip-filled furnaces at the Isabella plant where the segregation of the lumps and fine had manifested itself very clearly and had demonstrated how completely it could prevent the satisfactory working of the furnace.

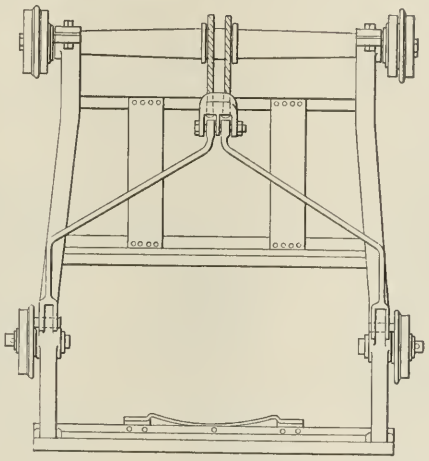
The top now to be described was designed by Mr. Neeland to overcome this difficulty, and it has been very successful in doing so. To accomplish this result he decided to use a type of bucket for hoisting the material which could be accurately centered on the furnace top before dumping, and then be dumped uniformly in all directions.

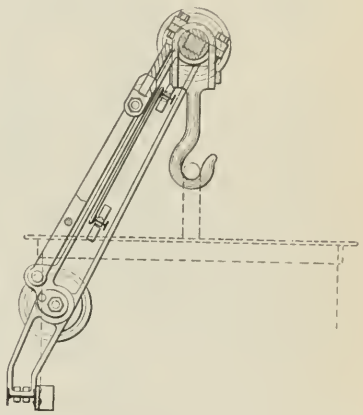
The huge bucket used has its bottom closed by a bell by the central rod of which the whole is suspended from the truck which ran on the inclined hoist. The general arrangement is shown by Fig. 22 (p. 226).

The scale cars on which the buckets are set run along under the double row of bins from which the buckets are charged with the required material. Each bucket in turn is then brought into the central plane of the skip where it is picked up by the hook on the inclined truck (Figs. 23 and 24) and carried to the top of the furnace. There the front end of the truck with the bucket hanging to it enters a vertical slide in the center line of the furnace top and is lowered vertically to a seat on the top of the gas seal. The further downward movement of the slide lets the bell bottom of the bucket pass down inside the gas seal carrying the counterweighted gas seal bell with it. The bucket then discharges and the return movement of the slide raises the bell-bottom of the bucket back to place, allows the gas seal to be sealed by its counterweight, and finally picks up the bucket itself on its own bell, and the return trip of the truck takes it back to the bottom where it is unhooked and another loaded bucket picked up. The arrangement is well shown by Figs. 25 and 26 which show the bucket resting on its seat in the furnace top and its bell on top of the gas seal bell.

It will be seen that there is no horizontal velocity whatever to the stock, and that if it is reasonably level in the bucket an equal amount is discharged on each sector of the bell. It is, in fact, as if the hopper of the double bell top were filled under the bins brought up to the top of the furnace and dumped, instead of being filled by the intervention of the skips. It is worthy of note that the bins are arranged in parallel rows on each side of the scale car tracks so that the buckets are filled alternately from opposite sides thus balancing up the irregularity which would have arisen from the great segregation on one side of the bucket had it been filled always from one side. At the same time it is no more than fair to add that Mr. Neeland had this matter of segregation very much in mind and he designed the bins with the shortest possible chutes to give a low delivery velocity and so arranged that the stream of material strikes as closely as possible on the apex of the bell bottom of the buckets.

In more recent years this system of filling has been improved by the addition of a motor on the scale truck which rotates the buckets either through a certain definite angle after they have been filled, increasing by a fixed amount for each bucketful, as for instance 90, 180 and 270 deg., or else the buckets are rotated continuously while charging, so that the charge may be distributed in uniform rings thus securing an equable distribution of lumps and fines in every portion.





FIGS. 23 AND 24—BUCKET CARRIAGE OF THE NEELAND TOP

Ford-Parkes Top

Various modifications of this type of filling system have been made. A general drawing of the Ford-Parkes design was shown in the second article of this series. The details of the top and bottom are shown by Figs. 27, 28, 29 and 30. The buckets in this design are not delivered onto a scale car, but onto a turntable carrying four bucket seats. This table is rotated 90 deg. at a time, and this rotation takes the empty bucket away and brings a freshly filled one to take its place. When the bucket is at 180 deg. from the position under the skipway, it is filled from the scale car which in this case is the regular hopper type of scale car. The general arrangement of the turntable and the motor for turning it are also clearly shown, also the scale car in position in Fig. 28.

The general design of the bucket-carrying truck is shown at the foot of the incline, the large quadrant at the front or upper end of the truck from which the pick-up hook hangs is clearly shown. This quadrant is rigidly attached to the rear wheel of the truck and pivoted on its own center in the center of the equalizer between the two front pairs of wheels. It is evident that if the rear wheel of the truck be swung up around the pivot as a center, that the hook carried by the chain

unwinding from the quadrant will move vertically downward.

Referring now to Fig. 30, showing the top of the incline, there will be seen the convex curve on which the two front pairs of wheels of the truck run, and above a guiding slot with a sharp reverse curve which acts as a guide for the rear pair of wheels. The upper portion of this guide is a circle struck from the center of the truck in its top position, and this circle permits the rear wheels of the truck to rise while holding the pivot of the quadrant rigidly in its place, and gives the required vertical movement to the bucket as a whole. This seats the bucket on top of the gas seal exactly as is done with the Duquesne top, but without the assistance of the vertical slide, and therefore somewhat more

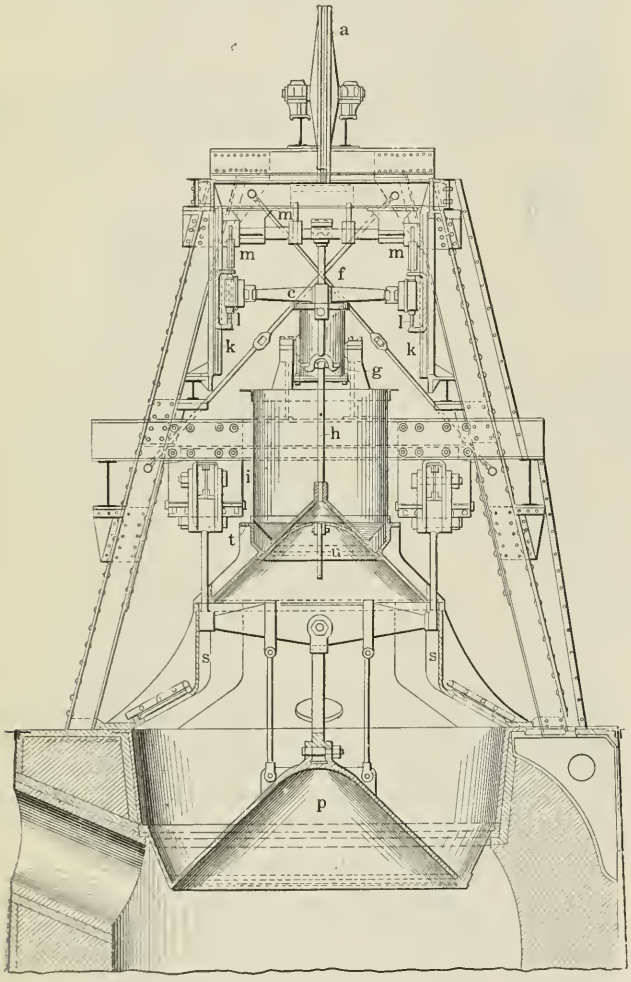


FIG. 25—DETAILS OF NEELAND TOP

simply. The return of the rear wheels to their normal position is secured by a heavy counterweight which the rear wheels pick up just before they enter the guide, and which pulls them back down on to the incline as soon as the hoisting rope is slacked. The head-shieve is clearly shown just above the curved guide.

Other modifications of this type of top have been built but the principle is no different from those illustrated in any of them.

At one of the most successful plants in the country the bucket is never unhooked from the carriage but rigidly attached to it just as the skip is attached to the hoisting rope, but provision is made for rotating the skip on its vertical axis to each of three equally spaced directions in turn, this eliminating irregularities in the charging of the skip.

It will be seen that this type of filling gives precisely the same type of distribution as the doube-bell type of top, and with almost the same limitations. That is to say, irregularities due to the way in which the charge is delivered into them may and generally do occur with either type of filling, and may be more or less completely compensated by the correct rotation of the receiving part to the different dumping points in regular order.

At the same time it must be recognized that the advantage is with the bucket system if the top be not rotated because of the smaller number and lower velocity of transfers of the stock with corresponding reduction of the opportunity for segregation.

Guiding the Bell Movement

One point of extreme practical importance in all types of furnace tops is the path of the main bell in its descent. It is obvious that if it be attached directly to the end of the bell lever the latter swinging as it does in the arc of a vertical circle will carry the bell in a similar path and it will be either one side or the other of the center of the furnace, in the plane of its motion, practically all

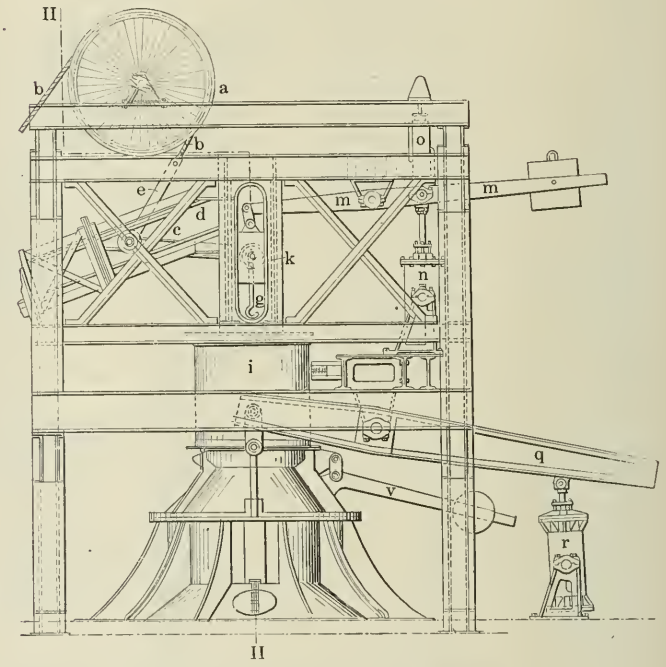
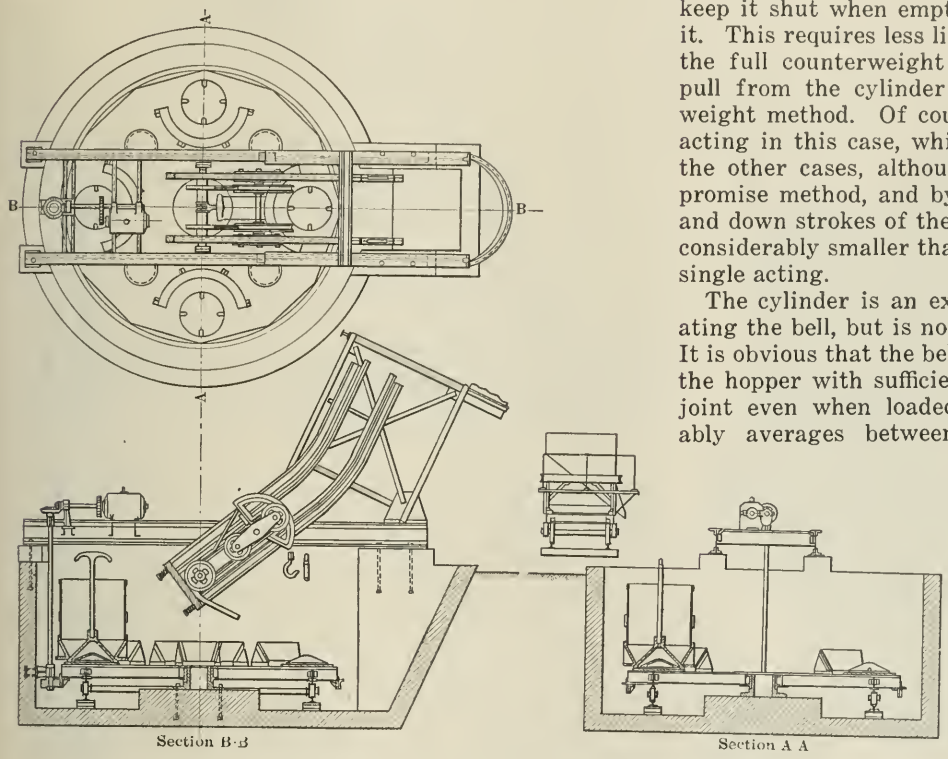


FIG. 26—DETAILS OF NEELAND TOP

the time. The projecting end of the bell lever is quite long, and it looks as though the curvature of the path described by it could be ignored, but this is by no means the case. The versed sine of the arc described always amounts to a couple of inches and may easily exceed this, which is enough to insure there being a considerably greater portion of the charge on one side of the furnace than on the other, and much bad furnace work has been attributable to this irregularity. The path of the bell rod must always be a straight line exactly in the center of the furnace. This straight line can be produced either by a rigid guide for the bell rod, connecting the latter to the lever with a short link; a quadrant from which a flexible suspension member unwraps always in a vertical line as the lever rises and falls, or a mechanical parallel motion similar to that of Watt's steam engine. A good illustration of the quadrant system is shown in Fig. 10, in which the bell is suspended from the triangles which are hung from chains working in grooves in the castings on the ends of the bell lever, these being segments of circles concentric with the center of the lever.

The parallel motion design is well shown by Fig. 12. The bell rod is not connected directly to the end of the

main bell lever but to a short link which projects above it, the upper end of which is guided by a connecting link pivoted to a projection on the fulcrum of the main bell lever. The proportions are such that the bottom point of the suspension link where it is attached to the bell rod moves in an absolutely straight line. In Fig. 12 the small bell is guided by the main bell rod and therefore is not provided with any parallel motion, only with a suspension link to connect the curved movement of the bell lever with the straight-line movement of the bell rod. But in many cases the lever of the small bell is provided with its own parallel motion also. The rigid guide is used on the Baker top, the (two) bell rods passing through guide castings riveted to the gas seal and others on the superstructure at the upper end of the rods. The bell-lever is connected to the rods by a short link as shown (but not very clearly) by the drawing.



FIGS. 27, 28 AND 29—BOTTOM OF FORD-PARKES SYSTEM

Bell-Operating Apparatus

In the early days of the closed-top furnace the bell was probably always controlled by a hand-operated "crab," consisting of a crank and connecting rod driven by gearing. A large gear having a crank pin in its face was set immediately under the outer end of the bell beam and a connecting rod ran from a pin in the bell beam to the crankpin in the gear. When the pin was in its lower position the bell was shut, and the travel of the pin was such that when it was in the opposite position the bell was opened wide. A few of these crabs have remained in operation down to quite recent years, but they were superseded in general practice many years ago by a steam cylinder as shown in several of the preceding figures.

There are two methods of using the cylinder. One is to counterweight the bell so that it will stay shut even with the full charge upon it, and have the cylinder lift the counterweight to open it. This has the great advantage that if the steam connections are broken or any other mishap takes place, the bell remains closed and prevents the entrance of air into the top of the furnace, which is necessary in order to prevent gas explosions.

In the other method of operating, the counterweight is dispensed with and the direct downward pull of the cylinder keeps the bell closed. This is somewhat simpler than the other method or at least permits doing away with the counterweight; moreover by operating in this way the cylinder can be placed at or near the bottom of the furnace and connected with the bell by means of a wire rope, but obviously this cannot be done when the bell is kept shut by a counterweight. However, a counterweight can be applied at the bottom of the rope and immediately over the top of the cylinder if desired.

In some cases a compromise method is used and the bell is counterweighted about to the extent which will keep it shut when empty but not with the charge upon it. This requires less lift from the cylinder to open than the full counterweight method, and also requires less pull from the cylinder to close than the non-counterweight method. Of course the cylinder is made double acting in this case, which it need not necessarily be in the other cases, although it usually is. By this compromise method, and by equalizing the work on the up and down strokes of the cylinder, the latter can be made considerably smaller than when it is virtually or actually single acting.

The cylinder is an extremely simple method of operating the bell, but is not a particularly satisfactory one. It is obvious that the bell must be held to its seat against the hopper with sufficient pressure to make a gas-tight joint even when loaded with the charge which probably averages between fifteen and thirty thousand pounds. The amount of work involved in opening and closing the bell is very small, and in order to be large enough to hold the bell shut or push it open by direct action the cylinder must be much too large for the real work it has to do, in order to form a satisfactory lock in holding the bell shut with the charge upon it.

On the other hand, any mechanism which exercises a reasonable control over the bell during the dumping operation and likewise in closing so as to prevent excessive velocity is practically sufficient, except in the case of the full counterweight method.

It is very desirable to have a relatively slow movement of the bell at opening and closing so as to prevent slamming and violent inertia shocks on the whole mechanism. For this purpose the bell cylinders are piped as shown in Fig. 19. Inlet takes place through the pipe next the end of the cylinder, but discharge can only take place freely through the one further in from the end, since the outer one contains a check which prevents return flow, at any but a very slow rate, so that when the piston overruns the outer port it is cushioned by the steam trapped between that and the head of the cylinder, and its velocity thus checked at a rate slow enough to do no harm.

The cylinders generally require to be operated by steam as compressed air for such purposes is expensive and is likely to be frozen up in winter. When the bell cylinder is placed at the top of the furnace great care must be used to prevent the pipes leading to it from being frozen since there is no flow except when the bell is operated, and in severe weather during a relatively short suspension of filling a sufficient interval may occur between piston movements to permit this to occur.

It will be seen that the crank and connecting rod has an absolutely smooth acceleration and retardation and that in the closed position it acts like an inverted toggle and holds the bell tight shut without expending any energy on it, so that it furnishes the ideal movement for this purpose. To make use of this ideal motion and to dispense with the necessity of steam or compressed air for operating bell cylinders an apparatus has been brought out in recent years which returns to the crank and connecting rod principle; but instead of being hand operated, as the earlier ones were, it is driven by an electrical motor controlled by automatic switches. The design brought out by the Otis Elevator Company is shown in Fig. 31. Fig. 32 on a smaller scale shows the arrangement of the crank in relation to the gear more plainly. The motor drives worm gears enclosed in the housing shown, and these in turn drive an internal pinion which meshes with the teeth of the annular gear. Automatic switches practically identical with those illustrated in connection with the furnace hoists control the movement of the apparatus. When the starting switch is closed the motor starts and runs until it has driven the main gear and the crank through a complete revolution, when it is automatically slowed down and stopped. This obviously opens the bell and closes it again. The only objection to this apparatus is its very considerable cost, and the necessity of having such an amount of machinery at the top of the furnace.

It may be said that while the cylinder has its disadvantages for operating bells, with certain modifications it could be made to do very much better than the direct acting cylinder, and in many ways almost equal to the expensive electrically operated apparatus without costing nearly so much.

The operation of gas seal bells is practically the same as that of large ones, although it requires very much smaller apparatus, since the loads to be carried are very much smaller and the small bell itself also weighs many hundred pounds less than the large one. In some cases now the upper bell is operated by an electrical bell hoist similar to but smaller than the one illustrated, for of course it is desirable to have both types of mechanism the same, to have either both steam or both electric.

These bells have generally been operated by cylinders working through levers the same as those used on the main bell, but several years ago Julian Kennedy of Pittsburg brought out a design in which the cylinder for the small bell was placed immediately over it in the center of the furnace in an inverted position, its piston rod becoming the rod of the small bell. This, of course, dispenses entirely with the lever for transmitting the motion, etc., but is open to the objection that steam must be on the cylinder practically all the time in order to keep the bell shut, or else a counterweight and lever must be used.

This design is followed with the riffle-barrel cylinder of the Baker top as already noted, but in that case the normal position of the small bell is open, so the cylinder is only under steam when the bell is being raised to close and rotate it.

Provisions for Access and Repairs—Means for Hoisting Main Bell

In the days when furnaces were hand filled and practically the only mechanism on the top was the single bell with its lever and bell cylinder, considerations of accessibility played no part, there being but little apparatus and that all in plain sight. When a bell had to be taken down from the top of the furnace or sent up it was hoisted out with some simple but powerful hoist; set on rails and skidded over to the platform of the hoist, commonly known as the cage, on which it was lowered

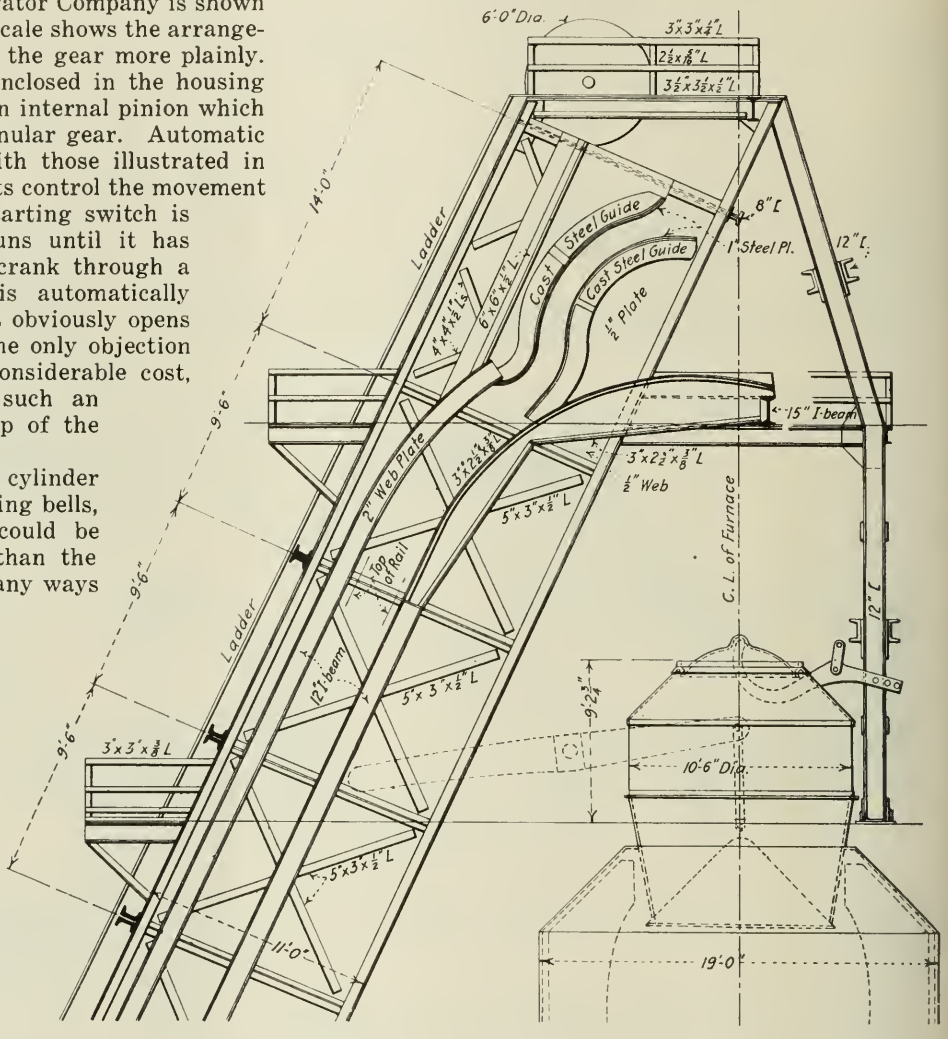


FIG. 30—TOP OF FORD-PARKES SYSTEM

to the bottom and a new one to replace it was brought up in the same way.

With the mechanical top all that is changed. There is in all cases a considerable quantity of machinery and in many designs a vast amount. This is erected when the furnace is built and is never expected to be removed until the furnace itself is torn down. The main bell is not only at the bottom of a hopper in many cases deeper than the height of a man, but is covered over by an air-tight gas seal so that access to it is most difficult even for inspection, while before any repairs can be made a considerable portion of the top must be dismantled.

This is a point which has been too little considered in the design of furnace tops. Some engineer in a cool and pleasant drafting room designs some form of apparatus which pleases his fancy, and which may then be built easily enough because its construction is fundamentally no different from that of any other mechanical apparatus. But when the repairs become necessary

they are turned over to the operating man, and must be made under circumstances which may be conservatively described as follows:

The temperature of every part that needs to be handled is high enough to burn the hand, in many cases so hot that the radiation makes it disagreeable to approach. Every crack and cranny is filtered full of dust that at the best is packed tight, and if it has been rained on is cemented almost as hard as iron. The air is not only heated almost to the point of suffocation in many cases, but in practically every case is mixed with furnace gas containing 25 per cent carbon-monoxide, of which 1 per cent in the atmosphere is quickly fatal, and a small fraction of a per cent causes violent sickness. The nut of every bolt is either burned or rusted fast, or so jammed with dust that it will move but one "flat" at a time, and often will not start at all except with a sledge hammer and chisel. The room available on the top platform is generally just sufficient to permit bare access around the top of the furnace when everything is in place. The little space in which one might move with safety or speed is seized for the storage of parts as soon as the top is dismantled for access to the bell and hopper.

Under these circumstances it would seem as though some consideration might be given to accessibility and to designing some of the parts, notably the gas seal, so that they would go to place and function properly without the necessity of coming to an exact position, something which it is almost impossible to make them do after all this machinery has been subjected to the heat if not flame which are unavoidable at the top of a furnace, but this point appears to have been given very little consideration.

In quite a number of types the gas seal which rests on the lip of the main hopper supports the distributor; this means that in order to change bells the whole distributor must be taken off and the gas seal completely dismantled before the real work of removing the bell can be started.

It will perhaps illustrate the operating man's point of view to explain the former method of holding the lip ring down to its seat in the hopper. This was almost universally done with square bars resting against the lip ring at the bottom and passing through a socket near the top of the hopper, a key in a key-way through the bar just below the socket was driven by a sledge so as to force the bar down against the upper edge of the lip-ring, thus holding it to place. It is obvious that when the lip ring became loosened by the constant jar of the bell in closing, these keys could only be tightened by putting a man into the gas seal through a manhole such, for instance, as that shown in Fig. 12, and having him drive up the keys.

It will be seen that he had to stand in a V-shaped space without a particle of footing, the temperature under the seal in many furnaces is seldom much less than two hundred degrees, even if means have been taken to cool it off, while there is almost certain to be a certain amount of gas leakage through the main bell and no chance of obtaining adequate ventilation through the small man-holes in the gas seal. I have known of at least one case where a man was killed by gas on going in under the gas seal to do some such work. The gas was not in sufficient quantity to be visible, and several men were rendered unconscious by it before the damage was realized, but by quick work on the part of the master mechanic all were taken out alive except the one.

In course of time the operating men determined that the holding bars for the lip ring must be tightened from outside the gas seal, and changed the construction to permit this, a practice which is now almost universally followed. The general principle of the method by which it is done is shown on the left hand side of the hopper in Fig. 18.

Of course, neither the hoisting apparatus for the skip nor that for the bucket system of filling affords any possibility of handling the bells, and, therefore, some other provision must always be made for letting down old bells and bringing up new ones. This is very generally in the form of a runway extending well out over the side of the furnace, as shown in Fig. 12. In this case the runway is the same as that which carries the adjustable receiving hopper. When a bell is to be handled the hopper is removed and the trolley shown at the extreme left hand end of the runway is brought into action. This trolley runs far enough out so that the bell hanging from it in its outmost position clears the furnace entirely and may be brought up vertically; then when it is above the hand-rail the trolley is traversed over to

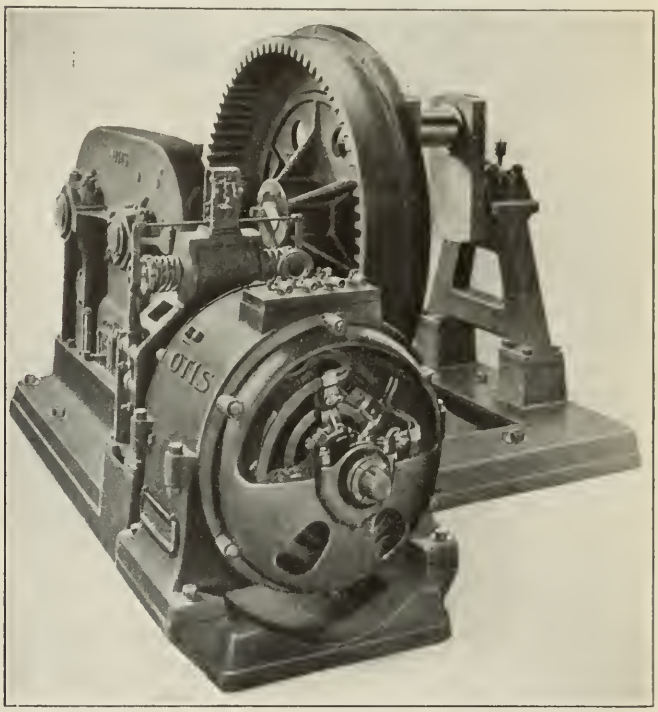


FIG. 31—DOUBLE SCREW INTERNAL GEARED ELECTRIC BELL HOIST, DIRECT CURRENT

the center of the furnace and the bell lowered into place. Sometimes a jib crane is used for this purpose, but in some cases within my experience these have been forced out of plumb by distortion of the furnace top and have been extremely hard to swing around, especially when under load. For this reason the runway with the traveler is probably much to be preferred. Ordinary hoisting arrangements cannot be used on the trolley on account of the great height of lift involved, and it is well to provide not only a trolley with its sheave, but to have some means of doing the hoisting quickly and safely.

Bells are certain to give out at intervals, probably their life does not average much over a year, and to have a good top design and good arrangements for hoisting and a top accessible without too much dismantling means the difference between a shut down of twelve and one of forty-eight hours.

The Stock Line Recorder

One of the most important points in connection with the filling of the blast furnace is to maintain the stock line at the proper height. With hand-filling this was frequently very difficult to do. The physical limitations of the apparatus, to say nothing of those of the men,

were such that if the furnace once "got down," that is if the stock line settled to a lower level than it should by the melting of the stock column below, it was very difficult to catch up as I have already explained. And if the stock line settles to the level which the stock should reach after it has been in the furnace for say two hours, then obviously the stock charged while that condition prevails is deprived of two hours of the time it should receive in treatment. This is frequently more than

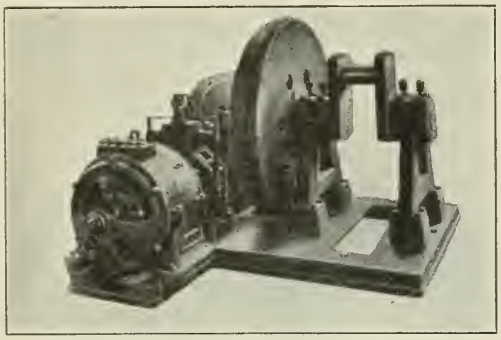


FIG. 32—BELL HOIST—CRANK END VIEW

enough to derange seriously the working of the furnace.

For this reason it is of great importance that the furnace shall not only receive in one twelve hours the complement of stock which it requires, but that this should be received at a uniform rate, and the stock line kept constantly within a very few feet of its proper position. When the furnace is filled with skips their capacity for handling materials is so vast that there is not often any physical obstacle to prevent the furnace from being kept full, but the very speed with which it may be charged may be a disadvantage since the men on the night shift may take a "spell" of an hour or two knowing that by hard work they can catch up by daylight, although the furnace may be "down" many feet when they begin to made up for the time lost, and its working deranged thereby.

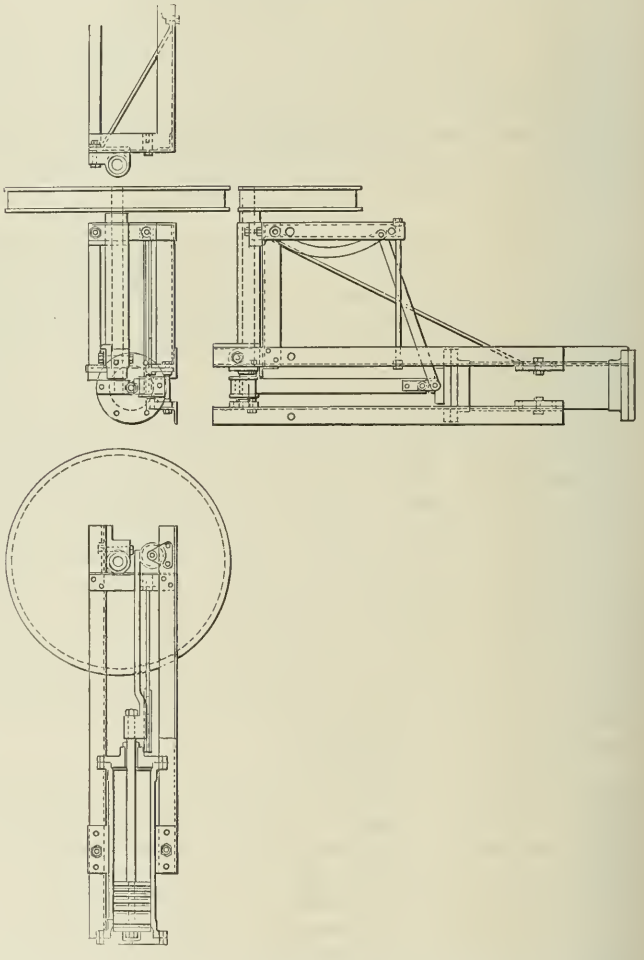
Gaging rods working through the top of the furnace, generally through the hopper or a point just back of its upper edge, have been provided ever since the introduction of the closed top, and in recent years since the introduction of skip-filling, arrangements have been made whereby the test rod is suspended from a rope which winds on a drum at the bottom of the furnace, and by operating this drum the furnace can be gaged without the necessity of going on top.

There is also another need to gage the stock line. This results from the fact that while the stock line ordinarily settles quite regularly, so many inches per minute, at times the furnace slips and the stock line will drop from two or three feet up to fifteen or twenty in moderate slips, and of course much greater depths in violent explosions and even though the furnace be working normally below it is much more desirable to have a record of the way the stockline is settling, so that any tendency to lag or work irregularly can be detected and cured without delay.

For the accomplishment of this purpose I designed several years ago an apparatus called a "Stock Line Recorder," of which the principle is very simple. (See Transact. *Amer. Inst. Min. Eng.*, Vol. XXXVI.) The test rod instead of being raised up out of action except when the furnace is to be gaged rests normally on the stock and settles with it. When the bell opens to admit the charge the test rod is drawn up out of the way, and when the bell closes it settles back on the stock in its new position, and follows it down until lifted for the next charge, and so on.

The mechanism by which this is accomplished is extremely simple, and the actuating portion of it is shown by Figs. 33, 34, 35. The test rod, which is made quite heavy, hangs in the furnace in the ordinary way. Light, flexible wire ropes are passed over a sheave on top of the furnace, and from thence to any convenient point, preferable near the skip operator's platform, where the actuating mechanism is placed.

The rope is wound on the narrow flanged drum, shown at the top in the plan view. This drum is keyed to a shaft, on the other end of which is keyed a small pinion meshing with a rack fastened to the piston rod of the cylinder shown below. The piston rod works through a metal gland with a fairly free fit so as to avoid friction. The piston is made quite heavy or else weight is attached to it in some way so that this weight acting through the pinion and drum tends to take up the slack from the test-rod rope, but on account of the much greater radius of action of the rope, and the considerable weight of the test rod, the weight of the piston alone cannot lift it. The top of the cylinder is connected to the main bell cylinder, generally without any valves or connections of any kind, so that when steam is turned on the main bell cylinder to open the bell it is simultaneously turned into the top of the recorder cylin-



FIGS. 33, 34 AND 35—OPERATING MECHANISM FOR STOCK-LINE RECORDER

der, and forcing the piston down raises the test rod to its highest or "safe" position.

When the steam is exhausted from the bell cylinder to close the bell it is simultaneously exhausted from the recorder cylinder, and the weight of the test rod with its greater leverage then lifts the piston in the cylinder until the test rod rests upon the stock, when it comes to rest and only moves thereafter as the test rod settles in following the stock down. The movement of the

mechanism is reduced by the lever shown in the back view (Fig. 34) and transmitted to the mechanical recorder, either of the dial or the strip type, and makes thereon a saw-toothed record as shown in Fig. 36. The amount of information obtainable as to the way the furnace is settling, whether steadily or by slips, is quite remarkable. One accustomed to the type of chart produced by a given furnace can tell by a glance at it whether the furnace is working normally or not, while the check on the fillers, on the human side, is an absolute one since it must work if the furnace is filled, and in a number of year's experience no method was ever found by which the machine could successfully be "beaten."

The subject of distribution is so vast, the number of variables and their reactions upon one another being practically infinite, and our knowledge of what the furnace really requires is so exceedingly limited, that the

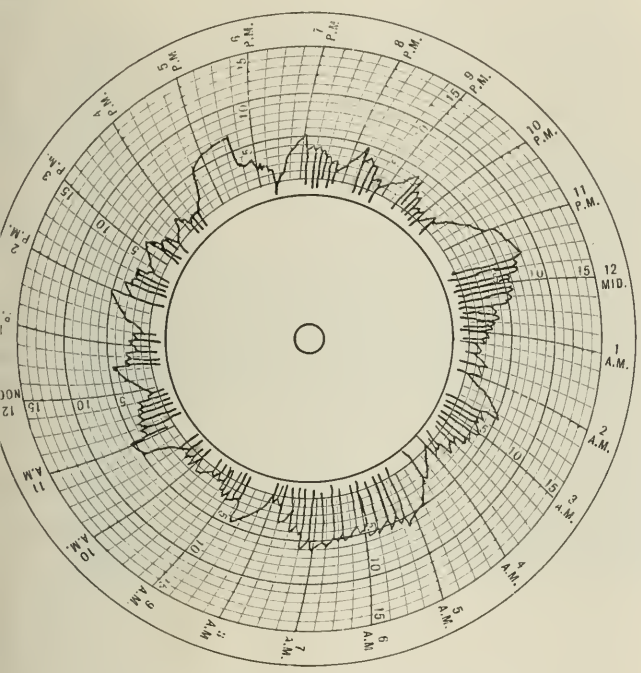


FIG. 36—CHART OF STOCK LINE RECORDER

little we know on the subject has only been developed by an utterly disproportionate amount of trial and experimentation, both with models and with furnaces, and by the slow process of elimination of the most unfit. It is probable that a book could be written upon the subject if one were willing to go back and compile the results of the experience of furnace men of the older generations.

But the question of whether we will or will not use mechanical filling for furnaces has been settled for us as have so many other questions, not upon the technical ground of whether its distribution is better than that of the hand-filled furnace, or the technical results better or worse than that of its predecessor, but by the stern law of necessity. The waning supply of men available for continuous heavy work, and the increasing wages which they command, combined with the absolute necessity of continuous operation irrespective of all other considerations, have forced us to adopt mechanical filling. There is no reason to believe that certain circumstances will ever alter so that large plants will be in a position to go back to hand-filling even if they should so desire.

It remains, therefore, only for us to use our best endeavors to find out the fundamental laws of distribution, and then to design an apparatus which will conform with those laws and survive under the conditions on the top of the furnace. These are that any apparatus placed there shall receive a scant inspection surely not oftener than once a shift; that a shut down for its repair or for overhauling will be tolerated certainly not oftener than once in six months; that it must operate twenty-four hours a day, and seven days a week; that it must practically always be almost at the limit of working temperature for ordinary machinery; that it must be not infrequently exposed to a much higher temperature and often to flame itself, and that it must work in an atmosphere composed largely of the dust of one of the most abrasive materials in the world. That, further, it shall receive its material with irregularities depending upon a thousand circumstances, and shall smooth these out and deliver the material properly to its place on the main bell. That it shall pass pieces of scrap iron up to several hundred pounds in weight, two or three feet in length, and of almost inconceivable roughness, without injury to itself, and without delay, and that finally the total height through which the material must pass in the performance of these operations shall be a minimum so that the coke shall be broken up as little as possible.

If in the scant twenty years which have elapsed since the mechanical top became widely introduced we have not achieved perfection in all these results it is perhaps nothing to cause surprise. In contemplating the long distance we have come from the vast amount of expensive labor, the derangements of the furnace due to frequent inability to keep it full and for the horrible results of the early attempts at mechanical filling, I think we have every reason to feel, if not satisfied, at least that we have made great headway, in one of the most difficult tasks of designing ever submitted to the engineer and metallurgist.

Hydrometallurgical Treatment of Michigan Copper Tailings

BY R. D. LEISK

The Calumet & Hecla Mining Company is developing a combination regrinding and leaching treatment for the accumulation of tailings below its great mill on Torch Lake. If successful the method will probably be applied to all the old mill dumps in the copper country which can be profitably worked. The process may also solve the problem of treating mine rock in which the copper is so finely divided and flaky that losses in ordinary milling treatment are excessive.

The cycle of treatment can easily be followed by reference to the accompanying diagram, Fig. 1, in which, however, no attempt is made to show detailed arrangement of plant or machinery. It should be first explained that the Calumet & Hecla at one time milled rock containing about 90 lb. of copper per ton, and that the milling practice of that day allowed millions of tons of tailings containing 13 lb. or more copper per ton to flow into Torch Lake. With the increased extraction made possible by modern milling methods these tailings have gradually developed into an asset.

The old tailings are to be taken from the bed of Torch Lake by a main dredge and conveyed by a pipe line supported on pontoons to a storage pond on the shore of the lake near the new plant. Here a set of suction pumps will elevate the pulp to a set of dewatering and classifying tanks. The slime from these tanks will pass over a set of Wilfley tables and the tailings from the tables will go to the leaching vats. The concentrates from the tables will of course go direct to the smeltery.

The sand from the classifying tanks will pass over dewatering screens onto a belt conveyor discharging into the storage bins of the regrinding plant which will contain 64 Hardinge mills. Pulp in the ratio of three

of water to one of solids will be fed to the mills at the rate of 35 tons per day for a 20-in. by 8-ft. mill. No classifier will be used on the discharge, as this would return coarse particles of copper for further grinding which is undesirable. The ground pulp will pass over Wilfley tables where free copper will be removed and the tailings discharged to the leaching plant.

The tailings which go into the leaching vats contain about one-half of the copper originally present in the sands. The chemistry of the leaching process depends upon a reaction well known in analytical chemistry, although its use for the recovery of copper on a commercial scale will be something new. The pulp contains too high a percentage of calcium carbonate for economical acid leaching. All copper which has gone through a milling treatment becomes covered with a slight film of

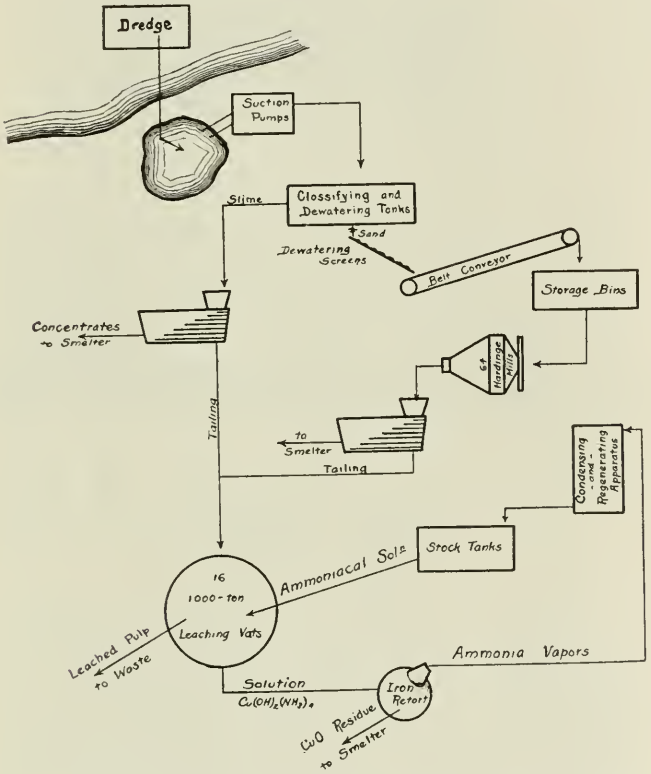


FIG. 1—DIAGRAM OF CALUMET AND HECLA COPPER LEACHING PROCESS

copper oxide which may be readily dissolved by ammonia in the presence of an ammonium salt such as ammonium carbonate.

$$CuO + 4NH_3.H.OH = Cu(OH)_2(NH_3)_4 + 3H_2O$$
(deep blue solution)

If a supply of oxygen is present in the solution, the film of oxide is at once renewed and the process is continuous until all the copper is consumed. The copper which is now in solution in the form of a double cuproammonium salt may be precipitated as oxide by distillation in ammonia-tight iron retorts. The ammonia vapor is recovered and regenerated, and the precipitated copper, in the form of oxide, may be mixed with grades from the stamp mill and charged to a reverberatory furnace. The process was first worked out in Germany on natural oxides and roasted ores, but the Calumet & Hecla Company is the first to apply it to native copper. Early experimenters precipitated the copper as sulphide by the use of H_2S, CaS, and BaS, but this is wasteful of ammonia and leaves the copper in an undesirable form for Michigan copper smelting equipment.

Plans for the leaching plant call for sixteen 1000-ton vats 54 ft. in diameter and 12 ft. deep. It is planned to complete the leaching treatment in a 91 to 96-hour cycle. In treating tailings containing 12 to 13 pounds of copper per ton it is expected to recover 5½ to 6 pounds on the tables and from 4½ to 5 pounds by leaching. The cost of leaching will be about 35 cents per ton and the recovery will be upwards of 70 per cent. The success of the process will depend upon how closely the working of the plant checks the results of the laboratory experiments, especially in the matter of losses of ammonia by volatilization. In the experimental work carried on by Mr. C. H. Benedict, the mill metallurgist, who has worked out the plans for the whole process, the working solution consisted of equal volumes of NH_4OH, specific gravity 0.93, and a saturated solution of $(NH_4)_2CO_3$. A more dilute solution will probably be used in the vats.

The plant is intended to run summer and winter. In winter the big dredge will be brought inshore and will dig in a small pond where the water can be warmed somewhat and kept in motion by the pumps. In summer the dredge, which has a greater capacity than the rest of the plant, will pump part of the sands into the excavation made the previous winter. The small pond in front of the second set of pumps is to give storage to tide over interruptions in the operation of the main dredge.

Work on the construction of the leaching plant has been halted temporarily, due to the general depression of the copper market, but the regrinding plant will be completed without delay. An interesting fact about the 40-hp motors which operate the Hardinge mills is that the electric power for them is developed by a low-pressure steam turbine driven by the exhaust steam from the stamps, which formerly was wasted.

Houghton, Mich.

Safety-First, First-Aid and Welfare Work of the Colorado Fuel and Iron Company

The safety and welfare of the employees of the Colorado Fuel and Iron Co. are administered through the medical and sociological departments, with headquarters at Pueblo, Colo., where the company's Minnequa steel works and Minnequa hospital are located. The Minnequa hospital has long held an enviable reputation among institutions of its kind. In the wake of its development and in harmony with the growth of a world-wide sentiment, have come those other evidences of attention to the human element suggested by the phrases "first aid," "safety first," and "welfare work."

Committees on Safety

The administration of the safety department in the Minnequa works is under the direction of Mr. F. E. Parks, assistant superintendent, and in the hands of a central committee and department committees comprising officials and employees. Department committees are charged with the inspection of conditions within their respective departments, observing and reporting dangerous conditions and recommending safeguards for the protection of workmen. Dangerous practices and careless habits of employees that might lead to preventable accidents also come under their observation and are made the subjects of reports. The reports are considered by the central committee, the superintendent of the department concerned and the reporting committee and plans are then laid for improvement in the dangerous practices or conditions. As a final safeguard the committeemen regularly inspect the provisions for safety to see that they are intact and in good repair.

The safety department was organized on its present basis in July, 1911. In the three succeeding years the

ompany spent over $20,000 in safety work. All sta-onary engines about the works have been equipped ith automatic speed-limiting devices. Overhead raveling cranes are provided with railings and guards. ubstantial platforms and railings have been erected long the trestles above receiving bins, and at over-ead valves in the works. Permanent stairways have een substituted for ladders at many places and rail-ngs and platforms provided at elevated points from hich a workman might fall during the discharge of is duties. Emery wheels are housed in adjustable teel guards designed at the works. Gears and motors re covered or surrounded by substantial iron-pipe ailings, and guards are placed about moving belts to revent accident in case of breaks. In some cases notors have been elevated so that the belts, properly uarded, run above the workmen's heads. In general, very precaution has been taken to prevent employees rom becoming accidentally entangled in moving ma-hinery.

The legend "Safety First" is before the workmen at ppropriate places, as shown in several of the accom-anying illustrations, being displayed with special rominence on a trestle in full view of all the men as hey pass over a viaduct to enter the works. The umbered brass check carried by every employee also ears the same words stamped on its face.

Physical Examination Required

In order to secure a class of employees fit for work n the plant and to avoid the employment of men who, hrough previous physical disqualification might be-ome a needless charge on the medical department, the ompany instituted in 1912 a system of examination or applicants. By this arrangement each applicant or employment is required to sign an application and ecord card and to pass a physical examination by a ompany surgeon. Table I shows the examination ecord. The examination is made at the Minnequa vorks dispensary without expense to the applicant. Boys under the age of 16 years and men over the age of 59 years or who are apparently under or over hose respective ages, are not accepted for employ-nent. Every employee is expected to be mentally and physically sound and fit for his work. An applicant is disqualified for employment if his examination re-veals any of the following physical disabilities:

"Loss of an eye, a hand or a foot, crippled, deafness, advanced tuberculosis in any form, epilepsy, fits or fainting spells of any character, active syphilis, running sores or any venereal disease, spinal affection heart disease, varicose veins, hernia, alcoholism, or any defect which would make it impossible for him to render regular and efficient service."

The diversity of races and nationalities represented among the employees adds to the problem of providing for their safety and welfare. Where men of only two or three nationalities are employed it is sometimes possible to post signs about the works, giving directions or cautions in several languages; but this is scarcely feasible where so many nationalities are represented. Table II gives a classification of 3689 employees of the Minnequa works, by races and departments as existing in August, 1914. The arrangement is in order of numerical predominance. Twenty-seven races are embraced. Americans predominate, comprising roughly one-third of the total; and for the most part they occupy the responsible positions. Austrians and Italians combined slightly exceed Americans in number and are employed mainly about the furnaces and in the mills.

FIG. 1—MINNEQUA HOSPITAL, WITH STEEL WORKS IN BACKGROUND

TABLE I.—APPLICATION AND EXAMINATION RECORD

Full Name of Applicant	Address		Nationality Age Married
Signature of Applicant In Presence of Person Issuing Application			Dependents and Address:
Signature of Person Issuing Application			
Name of Nearest Blood Relative	Relationship		Address
Name of Nearest Obtainable Relative	Relationship		Address
What Sickness Have You Had?			
What Injuries Have You Had?			
For What Have You Been Operated?			
What Physical or Mental Defects Has the Applicant?			
Has Vaccination Been Recent Enough to Insure Protection?	Qualified Disqualified		Signature Examiner
Signature of Applicant in Presence of Examiner	Date		Place

Table II.—Classification of Minnequa Works Employees by Races and Departments

Nationality of Race	Totals	Blast Furnace	Rail Mill	Open Hearth	40" Mill	Rod Mill	Wire Mills	12 & 14" Mills	9, 12 & 20" Mills	Spike Mill	Bolt Mill	Pipe Foundry	Casting Fdry.	Bottom House	Electrical	Power House	Power House Blrs.	East Side Blrs.	Machine Shop.	Boiler Shop	Pipe Shop	Smith Shop	Roll Shop	Carpenter Shop	Pattern Shop	All Shops	Stores	Yard	Masons	Watchmen	Stables	Timekeepers	Ore Crusher	Miscellaneous	East Side Gas	Loco. Cranes	Dodge Cranes	Drafting	Auditing	Laboratory	C. & W. Ry.	Totals
Americans	247	61	109	178	17	58	112	26	27	24	10	11	39	1	3	11	1	3	5	32	13	12	18	7	8	16	4	25	11	20	10	12	3	30	1	1	2	6	2	1	5	1112
Austrians	438	83	137	33	12	21	146	11	17	10	3	9	15	2	2	2	9	2	3	18	2	4	2	1	1	2	1	5	1	1	1	1	1	2	2	1	1	1	1	1	1	780
Italians	424	8	40	106	13	3	57	3	1	5	24	24	33	1	2	1	2	1	3	12	1	1	1	1	1	1	1	5	1	1	1	1	1	2	1	1	1	1	1	1	1	444
Russians	55	11	13	11	1	9	51	29	15	5	2	1	3	1	1	1	1	1	3	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	182
Greeks	154	8	44	12	1	13	68	3	2	1	1	14	24	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Negroes	706	47	20	2	3	6	12	6	3	2	1	2	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Germans	94	1	19	8	1	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Mexicans	85	7	8	2	1	1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Swedes	49	2	7	38	1	1	11	2	1	6	2	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Spaniards	46	1	2	2	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Japanese	64	2	1	9	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Irish	64	1	5	2	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Slavonians	79	2	11	9	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Hungarian	14	1	12	2	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
English	17	2	5	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Pollocks	23	1	8	2	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Scotch	10	1	5	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Welsh	9	1	3	4	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Syrian	16	1	1	3	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
French	16	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Servians	14	2	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Bohemian	13	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Croatian	13	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Norwegian	12	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Swiss	11	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Cuban	10	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Portuguese	10	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Not recorded	11	1	1	1	1	1	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	115
Totals	2325	247	438	424	55	154	706	94	85	49	46	64	135	15	38	14	18	64	64	79	14	17	23	10	9	16	16	14	130	90	32	18	31	26	61	178	13	2	14	8	7	7	188	3889

Rescue Car for the Fuel Department

The fuel department, under the superintendence of Mr. E. H. Weitzel, maintains a rescue car for use at the company's coal mines. The car is equipped with first-aid cabinets, safety lamps, rescue helmets and various apparatus for use in case of coal-mine explosions. Training in first-aid and rescue work is given miners, who are granted certificates of proficiency on completion of a required course of instruction. In order to aid employees in passing state examinations for responsible positions about the mines a correspondence school was organized by company officials and instruction was given by mail and through night schools in charge of representatives of the local division engineers. As a result of this work 265 men took examinations in 1913 and practically all were successful in securing state certificates as fire bosses and mine foremen.

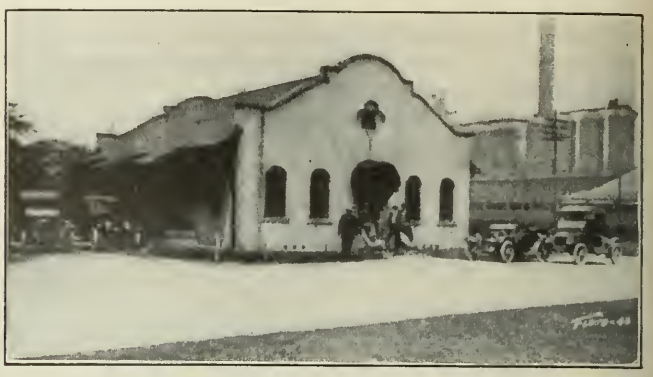


FIG. 2—STEEL WORKS DISPENSARY

Hospital and Dispensary Service

The proximity of the Minnequa hospital to the works, as shown in Fig. 1, and the location of the dispensary at the plant, Fig. 2, makes unnecessary the distribution of first-aid equipment throughout the various departments. The dispensary, under the direction of Dr. C. V. Marmaduke, affords medical treatment and handles minor surgical cases; gives vaccination to all employees without exception, and conducts an educational propaganda in prophylaxis. It is interesting to note that among the minor surgical cases, "foreign bodies in the eye" account for about 1000 each year, though the percentage of such accidents is

FIG. 3—SAFETY FIRST SIGNS ABOUT THE STEEL WORKS

claimed to be no greater at the Minnequa works than in other outdoor occupations.

The good effect of the safety work in the plant and of the required physical examination of applicants for employment is reflected in the dispensary report for the year ended July 1, 1914. Major injuries have been greatly reduced and the efforts to conserve health have shown commendable results that cannot be attributed to chance. In the matter of physical examination the records show that the percentage of rejections has fallen from 25 per cent during the twelve months following the adoption of the system to 15 per cent at the present time. This decline is accounted for by the general knowledge among possible applicants that the physical requirement for acceptance is held at a certain standard.

The Minnequa hospital affords treatment for sick and injured employees from the coal mines as well as from the steel works. The expenses and full railroad fare to and from the hospital are paid by this department. Employees who are helpless through permanent injury received in the company's service are kept at the hospital indefinitely, some having been

FIG. 4—SAFETY FIRST SIGNS ABOUT THE STEEL WORKS

there as long as 20 years. When space permits, the hospital is open to private cases on usual terms. This practice helps defray running expenses, aids in the maintenance of a competent staff and affords evidence to employes that they receive the same treatment as that accorded to patients who pay for the service. Even with this income, however, added to that received from the monthly charge on all employees, the company finds it necessary to meet an annual deficit for hospital maintenance.

Hospital Innovations

Under the direction of Dr. R. W. Corwin, chief surgeon for the company, the hospital has evolved from a small frame building containing 25 beds, in 1880, to the present magnificent institution with 216 beds. It is characterized by many innovations instituted by Dr. Corwin, that are not found at many other similar institutions. There are no stairways. The outer approach to the administration level, and inner connections between floors are by inclines on a grade of one foot in six, contributing to the ease with which healthy as well as sick persons can pass or be taken from one floor to another. This construction is illustrated in Fig. 6. Floors are covered with cork carpet; doors are of the noiseless swinging type and cannot be "slammed."

Every possible provision is made to eliminate dirt, odors and noise. Hospital signs bear the usual inscription "Safety First," and then admonish the reader to observe "Quiet Next." Special laboratories are provided for pathological and X-ray work. The operating room is specially interesting, having its floor, ceiling and three walls constructed of a continuous sheet of lead, while the fourth wall is formed of a large sheet of plate glass. The effect of the dull lead is to eliminate reflection of cross-lights, and it forms a surface

FIG. 5—SAFETY FIRST SIGNS ABOUT THE STEEL WORKS

that can be cleaned and sterilized by a jet of live steam.

For the education of employes in matters pertaining to health the hospital publishes regularly the *Sanitary and Sociological Bulletin.* This contains timely articles written in non-technical and popular form and is distributed free of charge. Illustrated lectures and entertainments are given periodically at the hospital chapel and residence.

Welfare Work

Special welfare work is conducted in the coal camps for the benefit of the miners and their families, under the direction of Rev. E. S. Gaddis, assisted by numerous

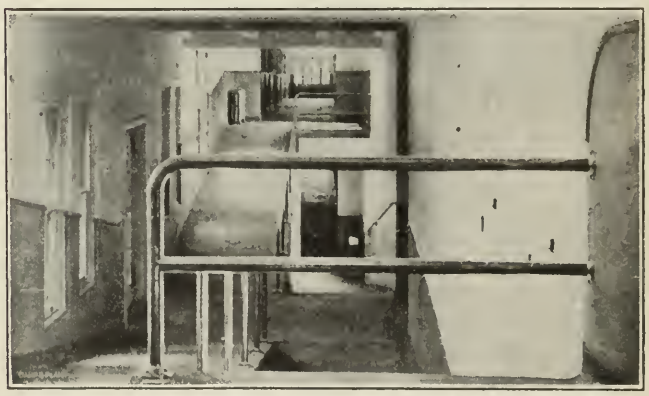


FIG. 6—VIEW OF INCLINE MINNEQUA HOSPITAL

local workers. Local company surgeons attend employes and their families, and maintain sanitary conditions in the camps. Education is under public control and regulation, as elsewhere in the state; but it receives attention from the sociological department, especially in the planning, lighting and ventilating of buildings and the activities of the pupils. First-aid exercises form a part of the instruction, even in the kindergarten. Reading rooms and social clubs are maintained for adults, and moving picture entertainments are given regularly.

The camps are also provided with churches, both Protestant and Catholic, in which services are held at regular intervals; and Bibles in several foreign languages as well as English are distributed free of charge.

During the recent labor troubles that occurred in the company's coal camps, saloons were closed by order of the State and remained closed during the greater part of 1914. From the opportunity thus afforded to observe the effects of enforced prohibition in the camps, the conclusion has been reached by company officials that the health, wealth and comfort of those communities were greatly enhanced. That this opinion was more widely shared is indicated by the fact that when the constitutional amendment for state-wide prohibition was before Colorado's voters last fall it was carried by large majorities in the strike districts where saloons had been arbitrarily closed for some time prior to election.

The Determination of Chromium and Vanadium in Steel

BY C. H. RICH AND G. C. WHITTAM

The oxidation of chromium by ammonium persulphate, as proposed by Walters,* has materially simplified the determination of that element.

Walters' method was proposed for the analysis of irons, usually of low chromium content. In adapting the method to the determination of chromium in steels, of 1 per cent or over, we have found that the oxidation of the chromium is incomplete in the volume of solution as prescribed by Walters. We have, therefore, modified the method to the extent of increasing the volume of solution at that point.

The combination of Walters' method for chromium and the J. Kent Smith method for vanadium, furnishes a very convenient method of procedure in the analysis of chrome-vanadium steels. Duplicate determinations of both chromium and vanadium may be carried through to completion in less than one hour and a single chromium determination may be completed in twenty minutes.

For those who prefer the internal indicator, the combination of the Walters and the Johnson methods, will be found convenient.

The critical points in the vanadium titration with the external indicator are the proper adjustment of conditions preparatory to the titration and the observance of a consistent end point, as subsequently to be described.

The Methods

CHROMIUM

One gram to 2 grams of the sample is transferred to a No. 4 lipless beaker and dissolved by heating with 40 cc to 60 cc dilute sulphuric acid (one part acid to five parts water). When in solution, 4 cc to 6 cc nitric acid (1.20 sp. gr.) is added and the solution is boiled until the iron is oxidized.

The solution is diluted to 170-180 cc and after the addition of 20 cc silver nitrate solution (1.33 grams per litre) is boiled during the addition of successive small portions of moist ammonium persulphate until the chromium is completely oxidized. The oxidation of the chromium is indicated in samples of low chromium content, by the precipitation of the manganese as dioxide, or, in samples of higher chromium, by the persistence of the pink tint of permanganic acid. The boiling is then continued a few minutes in order to decompose the excess of persulphate.

Two cubic centimeters, or slightly more if required, of strong hydrochloric acid is added and boiling is continued until the chlorine is completely expelled.

The solution is then cooled and diluted to 400 cc, a measured volume of the ferrous sulphate solution is added and the excess is titrated with the standard potassium permanganate solution. The percentage content of chromium is ascertained by appropriate calculation.

The ferrous sulphate solution is in close agreement with the permanganate solution, which is approximately $n/10$, standardized against sodium oxalate.

The relative value of the solutions is found by titration of 2 grams of plain carbon steel under conditions identical to those in the actual analysis.

VANADIUM

The slight excess of permanganate representing the end point of the chromium titration, is discharged by the necessary additions of the ferrous sulphate solution; one to two drops of permanganate solution is added and the resultant pink tint is discharged by careful additions of the $n/20$ ferrous sulphate.

A measured volume of the ferrous sulphate solution is then added and the excess is titrated with the standard potassium bichromate. The end-point in the titration is the first appearance of the momentary flush which spreads over the drop of ferricyanide upon the addition of the test drop.

Very small drops of the indicator are used, spaced upon the clean and smooth paraffined surface of a porcelain plate.

The test drop is dropped on the edge, rather than directly on top of the drop of ferricyanide. If there is difficulty in distinguishing the flush, the test drop is placed on the plate and is blown into the indicator by gentle blast through a piece of glass tubing: the flush is thereby rendered distinct.

The relative value of the bichromate and ferrous sulphate solutions is found by adding to the solution of 2 grams of plain carbon steel the same relative volume of the ferrous sulphate solution as is to be used in the actual analysis and titrating with the bichromate solution under the same conditions of control as in the analysis.

A more convenient method of procedure in either the chromium or the vanadium titrations, is to ascertain the relation of the respective ferrous sulphate and the permanganate and bichromate solutions, in acidified water solutions, and in the analysis account for blanks as determined in solutions of plain carbon steel. Blanks so obtained appear to be consistent and need be determined or verified, only at intervals.

Some results obtained are:

SYNTHETIC STEEL

Chromium		Vanadium	
Added	Found	Added	Found
3.88	3.85	0.25	0.23
3.10	3.07	0.21	0.20
4.97	4.96	0.25	0.255
4.97	4.92	0.25	0.242
4.97	4.97	0.25	0.242
4.97	4.96	0.125	0.127
4.97	4.96	0.146	0.153
6.22	6.17	0.125	0.127

The following vanadium results were obtained in synthetic steels of chromium content ranging from 3 per cent to 6 per cent but on which the chromium results were low owing to too concentrated solution in the oxidation of the chromium.

Vandium	
Taken	Found
0.25	0.23
0.21	0.20
0.50	0.49
0.25	0.248
0.25	0.242
0.125	0.127

*Metallurgical & Chemical Engineering, Vol. XII—No. 5.

Standard Sample No. 30—Bureau of Standards

Chromium	Vanadium
1.39	0.216
1.38	0.204
1.39	0.21
1.38	0.21

The results reported by the co-operating chemists on this sample, varied from 1.33 to 1.38 chromium with a mean of 1.35. The vanadium results ranged from 0.185 to 0.224 with a mean of 0.21.

Additional chromium was added to this sample with results as follows:

Chromium		Vanadium
Total	Found	
4.13	4.14	0.21
4.13	4.15	0.21

Laboratory of the Alan Wood Iron & Steel Company, Conshohocken, Pa.

Removal of Carbon Bisulphide from Coal-Gas

In London *Engineering* of February 19 an interesting account is given of a recent lecture by Mr. E. V. EVANS before the Society of Chemical Industry on the way in which, after many years of varied experimenting, the South Metropolitan Gas Company has succeeded in getting rid of the obnoxious carbon bisulphide always present in coal-gas. "To Mr. Evans and to his chief, Dr. Charles Carpenter, the main credit is due for this triumph of engineering chemistry."

The amount of sulphur compounds, mainly carbon bisulphide (CS_2) remaining in coal-gas after the extraction of the sulphuretted hydrogen or hydrogen sulphide (H_2S) is only 0.02 per cent. That really is the chief trouble. At such high dilution only reactions of high velocity are likely to be effective.

Three methods appear available for the removal of the CS_2. The first rests on the absorption of both H_2S and CS_2 by lime or other alkaline earths and alkalis with the formation of a thiocarbonate. Unfortunately the lime absorbs also the carbon dioxide, which is a superfluous, though not an obnoxious, constituent of the gas, and prohibitive quantities of lime would be needed for this purpose. If not removed, however, the CO_2 decomposes the thiocarbonate; any oxygen present has the same effect, and attempts to regenerate the decomposed mass *in situ* have so far failed. The "athion" process, now on trial at Heidelberg, is open to the same objection that the carbon dioxide has first to be removed; the absorbent used there is alkaline cellulose. Absorption by solids is always slow, moreover; but liquid ammonia has not answered either; thus this first method is not promising.

The second method relies on the absorption of the CS_2 by amino compounds (aniline, toluidine, etc.) in the presence of a catalyst with the formation of thiocarbanilides, which form the starting point of the manufacture of artificial indigo by Sandmeyer's reaction. The products are volatile, however, and the cost of washing the gas with weak acids or oils to bind the amino componnds would be high.

The third method, which has now proved successful, is based on the observations by Vernon Harcourt and others that most of the sulphur compounds in coal-gas are decomposed and converted into hydrogen sulphide, H_2S (which is subsequently absorbed by iron oxide), when the gas is heated to 500 deg. C. Mr. Evans took this line of research up in 1908. He found that CS_2 was not decomposed when carried by a current of nitrogen, but that the reaction did take place, according to $CS_2 + 2H_2 = 2H_2S + C$, and was irreversible, moreover, when hydrogen or coal-gas acted as carrier for small percentages of carbon bisulphide; the presence of water vapor did not disturb the reaction, which, it is noteworthy, depends upon the action of hydrogen, not of steam. The presence of certain metallic catalysts, of large porosity (finely divided so as to offer large surface) accelerated this reaction; the carbon liberated by the reaction was deposited in the pores of the catalysts, but could be burned out again *in situ*.

Iron proved the most active catalyst available at low cost; the decomposition temperature was 450 deg. to 500 deg.; for the regeneration (by combustion or aeration) of the catalyst, the iron had to be heated to 450 deg. for several weeks; iron pipes answered as containers for the catalyst. Having ascertained the suitable volume and weight ratios, and found that 80 per cent of the CS_2 could be eliminated by the new process without deteriorating by the heating the quality of the coal gas, Mr. Evans had an iron retort made to deal with 50,000 cu. ft. (instead of 10 cu. ft.) per hour. The jump was too great. In spite of the interposition of a tubular heat-interchanger, the enormous volume of gas cooled the catalyst so much that hardly any decomposition took place, even when the retort was red-hot outside, and when the regeneration of the catalyst was tried a hole was burned in the retort.

Attempts were then made with porous clay impregnated with metallic solutions. In that condition iron

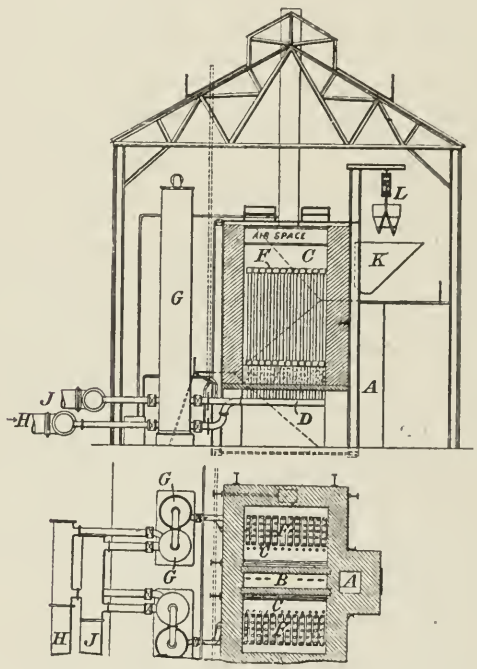


FIG. 1—PLANT FOR REMOVAL OF CARBON BISULPHIDE FROM COAL GAS

oxide was not active enough; nickel (reduced by hydrogen from the chloride) answered, but a higher temperature (600 deg.) seemed to be required for the reaction. That was undesirable, lest the coal-gas should be impoverished, and the deposition of carbon in the pores proved troublesome.

After a great deal of experimenting, in apparatus capable of dealing with 2000 cu. ft. of gas per hour, on the preheating of the gas, the amount, porosity, density and specific heat of the catalyst, the exposed surfaces of the catalysts and their containers and other features, a plant for 2,000,000 cu. ft. of gas per day was erected in 1911, and this was followed by a plant of five times that capacity (10,000,000 cu. ft. per day) in 1913. In these plants the gas is preheated by passing through 2-in. horizontal tubes before entering the four vertical reaction tubes, 6 in. in diameter, connected in parallel, the whole set being placed within the heating chamber. Such a unit dealt with 5000 cu. ft. of gas per hour, and in large plants a proportionate number of units were installed.

When Mr. Evans delivered his lecture the 1913 plant

had been in constant operation for almost two years, and, on an average, the percentage of sulphur compounds has been reduced to 2 per cent of the amount before treatment, that is, from 35 grains per 100 cu. ft. to 8 or 7 grains. In other respects the treatment makes little difference. The candle power and the thermal value are practically unchanged. There is a slight rise in methane (from 26.85 to 27.26). A little ammonia also results from the treatment. This is an advantageous feature, inasmuch as the ammonia keeps the iron oxide (wanted for absorbing the H_2S formed by the reaction) alkaline.

The catalytic material is a mixture of finely divided nickel (reduced from the chloride) and of a small quantity of nickel sulphide; the latter amount depends upon the ratio of H_2S to H in the original gas. Most of the sulphuretted hydrogen of the crude gas has to be removed before the treatment, otherwise carbon oxysulphide (COS) is formed by the interaction of the CS_2 and the CO in contact with the hot catalyst, and the presence of this undesirable COS becomes perceptible when the crude gas contains more than 100 grains of H_2S per 100 cu. ft. The above-mentioned increase in the methane percentage would be greater if the reaction were conducted under different conditions; it is partly the presence of sulphur which keeps it so low in the process under notice, because sulphur acts as a poison as regards methane production in the presence of nickel. It is interesting, as Dr. H. G. Colman emphasized during the discussion, that nickel is poisoned as a catalyst by sulphur at 250 deg., but is so no longer at 450 deg. The contact between nickel and carbon monoxide might be thought to lead to the formation of nickel carbonyl; the Mond nickel reduction process is based upon the fact that nickel and carbon monoxide form a volatile compound at about 100 deg. C., which is decomposed with deposition of metallic nickel above 200 deg. C. The presence of this poisonous nickel carbonyl in coal-gas, from which nickel might afterward be deposited, would be most objectionable. No trace of nickel has, however, ever been detected in the gas treated by the Evans process, even when the working temperature had been lowered to 250 deg. C.; yet, to make sure of its exclusion, contact between the gas and the nickel is not allowed to take place at a temperature below 300 deg.

The latest and largest of these installations is the plant put up at East Greenwich in the early part of 1914. The capacity of the plant is 15,000,000 cu. ft. of gas per day; it is divided into five units, each of 3,000,000 cu. ft. The 2-in. preheating pipes have, at Greenwich, been replaced by heat-interchangers erected outside the furnace setting. The general arrangements are illustrated in Fig. 1. Each unit consists of a central producer *A* surmounted by a combustion chamber *B;* on both sides of *B* are heating chambers, in which a temperature of from 420 deg. to 440 deg. C. is maintained about the reaction tubes *F* containing the catalyst. The gas entering through the pipes *H* is preheated to a small extent in *C;* the chief preheating takes place in the heat-interchangers *G*, in which the gas flows in the opposite direction to that requiring treatment; *D* is the collector tube and *J* the pipe carrying off the treated gas; *K* indicates the hopper and *L* the coke-handling plant. When the catalyst is to be revived, the temperature in the heating chamber is lowered and air is pumped through the reaction tubes at a definite rate, this process requires about a week, during the first four days of which all the oxygen of the air is taken up by the carbon deposited in the catalyst and burned to carbon dioxide. When oxygen appears in the effluent gas the temperature in *C* is raised to 430 deg. C and is kept at that height until the evolution of CO_2 has ceased. The aeration period is then complete, and before starting the decomposition the air left in the pipe system is swept out with waste combustion gases; similarly, the gas is swept out by combustion gases when preparing for aeration. The catalyst remains active in its tubes for thirty or thirty-five days, then the efficiency falls off and is restored by the aeration process just described. No deterioration of the nickel has so far been noticed after two years' working.

The capital outlay for plant per million cubic feet of gas per days was estimated by Mr. Evans to be about £1,500 ($7,500) and the working cost at 0.3d. (0.6 cent) per 1000 cu. ft. of gas, this latter figure including interest on capital, depreciation, repair and maintenance. This expenditure is not prohibitive. As has already been stated, some sulphur—7 or 8 grains per 100 cu. ft. —is still left in the gas. This sulphur is mainly present as thiophen, but there are other organic sulphur compounds not yet identified. Various methods have been tried to remove them, so far without real success. In Sweden the carbon bisulphide itself has been eliminated by washing the gas with alcohol, which absorbs the thiophen as well as the CS_2. This process is to be tried in England. The advantage of the alcohol treatment, as well as of the Evans process, is that the gas can be treated as such without previous removal of the carbon dioxide.

Standard Boiler Specifications

One of the most notable achievements of any engineering society is that of the American Society of Mechanical Engineers in connection with standard boiler specifications. This society some four years ago appointed a committee of seven prominent engineers to "formulate standard specifications for boilers and other pressure vessels and for care of same in service," in order to put an end to the increasing number of boiler explosions in this country and the resultant fearful toll of death and destruction.

The members of this Boiler Code Committee upon their appointment immediately set to work to draw up according to their best judgment a set of rules which would specify boilers of such high type that boiler explosions would be reduced to a minimum.

Each member gave unstintingly of his time and money to make this formulation of rules a success and, after three years of the most effective research work, a preliminary draft of rules was drawn up and sent confidentially to professors of engineering in prominent technical schools of this country, superintendents of inspection, departments of insurance companies, chief inspectors in charge of United States, State and municipal boiler inspection departments, prominent engineers known to be interested in the construction and safe operation of steam boilers, prominent manufacturers of steam boilers and editors of engineering journals—some two thousand persons. Each one was invited to read over this report, criticise the same and make any suggestions if they so desired.

An Advisory Committee was appointed in December, 1914, and from that time until the middle of February, they worked unceasingly, until the report was finally completed.

This report was presented to the Council of the American Society of Mechanical Engineers, February 13, 1915, and the Council voted unanimously to accept the report, and further than that, they voted to make the Boiler Code Committee and its Advisory Committee permanent under the name of the Boiler Code Committee of the American Society of Mechanical Engineers.

Fixation of Atmospheric Nitrogen

The fixation of atmospheric nitrogen was the subject two papers presented on the evening of March 12, 15, in a joint meeting of the American Institute of ectrical Engineers and the New York Section of the nerican Electrochemical Society. President Paul M. ncoln of the American Institute of Electrical Engi- ers presided.

General Review of Nitrogen Fixation Processes

The first paper was presented by Mr. **Leland L. mmers**, of L. L. Summers & Company, Chicago, Ill., d gave a very good résumé of the whole subject. The per is printed in full in the March issue of the *oceedings* of the American Institute of Electrical ngineers (p. 337 to 371).

The three fundamental products formed by nitrogen e, first, its union with oxygen to form nitrates XNO_3 d nitrites XNO_2; second, its union with carbon to rm cyanogen C_2N_2 and producing cyanides XCN and anamides XCN_2; third, its union with hydrogen, rming ammonia, NH_3. The present industrial situa- n with respect to these three groups of nitrogen prod- ts is reviewed. The available nitrogen in the various mpounds determines the price, at least as far as their e in the fertilizing field is concerned, and for a num- r of years it has been assumed that the selling price combined nitrogen would be from 12 to 13 cents a und.

The author gives a review of the different fixation ocesses which have been proposed, and then discusses some length the theoretical limitations of arc proc- ses on the basis of the thermodyamical theory of the uilibrium between N_2, O_2 and NO and the reaction locity of the formation and dissociation of NO—if e reaction is a purely thermal one. "We may assume at up to the present the [arc] processes in commercial e are limited strictly by the thermodynamic equili- ium of the Van't Hoff equation. As the volume of ses when working with low concentrations of NO are nsiderable, the radiation and convection losses as well the transfer of sensible and latent heat from the arc the gases lower very materially the temperature of e arcs, and the yields therefore indicate an average orking temperature of 2200 deg. Cent. to 2500 deg. ent. or concentrations of 1.5 to 2 per cent NO when orking with air. These theoretical limitations of the rect process of forming NO have, therefore, led to any efforts to dissociate the nitrogen molecule by her means."

The common elements exhibiting the most pro- ounced tendency to combine with nitrogen (in the sence of oxygen) are Ca, Mg, Al, B and the carbides a large number of metals. The author gives the eoretical reasons why for such processes the actions nd reactions must not only be subject to accurate tem- erature regulation but the partial pressures must be ntrolled and it is probable that definite zones of re- tion must be maintained.

Mr. Summers then takes up the description of those rocesses which have been commercially applied. Of rc processes for nitric acid production there are three: irkeland-Eyde, Schoenherr and Pauling (all of which ave been described and illustrated formerly in this ournal).

The latest Birkeland-Eyde furnaces are of 3000 kw apacity and give concentrations of about 2 per cent NO and a yield of 580 to 600 kg of nitric acid per w-year, or 65 to 70 grams of nitric acid per kw-hour.

The largest Schoenherr furnaces are of 800 kw apacity and maintain an arc 23 ft. (7 meters) long. hey give an NO concentration of 2.25 per cent and a yield of 550 to 575 kg per kw-year, or 65 grams per kw-hour.

For the Pauling process the percentage of NO obtained is 1.25 to 1.5 per cent in the 400-kw furnace, while the yields are 525 to 540 kg per kw-year, or 60 grams per kw-hour.

In all these processes where the arc is distorted the power factor is about 70 per cent, being about 5 per cent lower in the Schoenherr type.

All of the above concentration figures indicate that the maximum temperature of the arc is not utilized, but is very considerably reduced by the large amount of air admitted. If the temperature of the arc is raised by admitting less air there is a heavier decomposition of the products and all products are heated to a higher temperature with a corresponding loss, the net result being a lower yield per kw-hour. As the yield per kw-hour is of fundamental importance, adjustments are governed accordingly. The concentration of NO effects directly the apparatus for recovering the products, such as the absorbing towers, and the lower the concentration of NO the greater the losses from heating the inert gases. The furnace efficiency will largely be determined by this factor. A numerical example is figured out.

The author gives brief notes on Hausser's process utilizing coke oven gases by means of an explosion bomb, and points out that all of the above nitric acid processes utilize the reaction

$$2NO + O_2 = 2NO_2$$

which is an exorthermic one for the formation of the peroxide, and if the temperatures are controlled, side reactions can be prevented and equilibrium can be maintained with only a small percentage of NO remaining. The gases after leaving the furnaces are usually carried through waste heat boilers where 50 to 60 per cent of the heat is utilized for steam production. They are then cooled in aluminium pipe coolers and allowed to enter a gas holder where time is given to form the peroxide. The products then enter counter-current absorption towers where the reaction with water forms

$$2NO_2 + H_2O = HNO_3 + HNO_2$$

the nitrous acid HNO_2 is further oxidized and utilized to form HNO_3 in contact with the excess oxygen in the gases and with the absorbing water. The final recovery is usually made by circulating the gases through two towers of weak alkaline solution, such as sodium carbonate and this is converted into sodium nitrate and into sodium nitrite, and recovered by evaporation, the final products are a combined nitrate-nitrite of sodium. A normal circulation over three absorbing towers gives an acid of about 30 per cent concentration, but this can be increased to 45 or 50 per cent by recirculating over the first tower. Further concentrations are usually made by evaporation. All of these processes are simplified by increased concentrations of NO in the initial reaction. About 2 to 3 per cent of the original NO is discharged in the waste gases from the absorbing towers. It will be noted that one great advantage of these processes is that they require the handling of only air, gas and water up to the time the nitric acid is formed in the absorbing towers, so that the simplest handling devices suffice, and the labor is a minimum, also no chemicals are required until the final washing with the alkaline solution in the absorbing towers, and this may be a cheap solution such as lime water if conditions make it desirable.

The author then gives brief descriptions of the cyanamid process, the Serpek aluminium nitride process and the Haber synthetic ammonia process, and finally discusses the economics of nitrogen fixation.

Nitrogen is only one of the three important ingre-

dients of fertilizers, the other two being phosphorus and potassium.

"Prices of Nitrogen.—In general the price of combined nitrogen is fixed by the price of Chile nitrate. If this sells for 2 cents per pound and contains 15 per cent N, the price per pound of N is 13.2 cents and this in turn would make the price of ammonia sulphate having 21 per cent of nitrogen 2.7 cents per pound. These have been current prices. In considering the production of nitrogen products it would seem that while these prices control nitrogen for the fertilizer industry it would be desirable to produce if possible products which are manufactured from these crude products, and thus avoid competition with the natural products direct. Nitric acid of commerce is manufactured from soda nitrate by treatment with sulphuric acid, about 72 per cent of the sodium nitrate being nitric acid. As the by-products of this operation only partially pay the costs, the manufacturing costs leave the nitric acid with a value of 50 per cent over the value as nitrate. Hence chemical works could afford to produce nitric acid when they could not afford to add a manufacturing cost to produce a fertilizer from the nitric acid and then sell it in competition with the crude Chile nitrate.

"A large portion of the phosphate rock of this country is treated with sulphuric acid to form the so-called super phosphates. If nitric acid is used in place of sulphuric acid the super phosphate can be produced at the same time as a fertilizer of lime nitrate, or if preferred a high concentration of phosphoric acid can be produced from lower grade phosphate rock. Industries of this kind promise more favorable results commercially than does the direct production of fertilizer. If low grade products are manufactured at close prices a very large volume of business is a necessity and works of this character and magnitude are more apt to be a result of successful development rather than an initial venture in a field beset with uncertainties as to the profits and the chances of a development of other processes reducing these if they are problematical.

"Costs of Making Products.—Let us consider more in detail some of the costs. We may assume approximately that the labor and repairs in furnace room and absorbing tower will cost $10 per ton of nitric acid and if nitric acid is selling for $60 per ton, we have a margin for power cost, interest, general expense, etc., of $50, and if we produce 500 kg of acid per kw-year it will require 2 kw-year per metric ton or $25 per kw-year, and we must absorb all interest charges and general expense in this. If the yield can be made 550 kg per kw-year and we can sell for $60 per short ton, we will require 1.8 kw-year, or $28 per kw-year. We must assume that the product does not have to be packed for shipment and that there are no selling costs involved, and we must figure on an output so that our units may be large enough to bring the investment in plant down to $80 per ton of acid so the annual charge may be $8 or net $20 per kw-year, and if $5 are allowed for general expense the best we can do will be about $15 per kw-year.

"We see it would be hopeless to attempt to put this acid into a product to compete with the fertilizer prices, for they are some 50 per cent lower in selling price, and it will involve a cost for some raw material to mix with the acid, the cost of manufacture and a packing and shipping charge. We must then abandon any idea of making fertilizer from nitric acid prepared by the direct oxidation of atmospheric nitrogen in the electric arc until such time as we can improve the very low efficiency due to the thermodynamic limitations of the reaction. We can only hope to utilize this process in the manufacture of nitric acid coupled with some other product which will procure for it a higher price. There is for example a limited demand for the nitrite of sodium $NaNO_2$ used in the dye industry and this is manufactured by reducing nitric acid with molten lead thereby adding another manufacturing operation to the acid cost. This nitrite may be cheaply made by taking a mixture of NO and NO_2 such as we would have in parts of the system and passing it into water or sodium hydroxide,thus

$$NO_2 + NO + H_2O = 2\,HNO_2$$

or

$$4\,NO + 2\,NaOH = N_2O + 2\,NaNO_2 + H_2O$$

and this process would produce a product selling for 4 to 5 cents per pound. We must remember, however, that the price of nitric acid is not a fixture and that a cheap combined nitrogen fertilizer will cut the price of sodium nitrate and hence the price of nitric acid. We are confronted then with the fact that all processes will be affected by the success of any one process that is a large enough success to affect the market conditions of combined nitrogen and upset the ruling prices in the fertilizer industry. It is useless to look only to cheap power as a solution of this problem as the real solution is in the improvement of processes.

"Let us roughly compare the power requirements of the processes as we have outlined them and we find

Direct oxidizing of atmospheric nitrogen 5 per cent. efficiency, yield at 550 kg. per kw-year, requires per kg. of N	65 kw-hr.
Cyanamide process 66 per cent efficiency in carbide 1 per cent loss in heating to combine with N., requires per kg. of N. Also preparation of N.	16.6 "
Aluminum nitride using coal to heat products to temperature of reaction requires per kg. of N	12 "
Catalytic method of combining N and H to form ammonia, requires per kg. of N. Also preparation N and H, refrigeration, and compression to 200 atmospheres.	1.5 "

"The general tendency abroad in figuring the cost of water power is to give only the operating costs and from this one sees costs of producing power figured at from 50 cents to $1 per kw-year and in using these figures erroneous ideas have been widely circulated. In this country it has been standard practice to consider the investment in the power plant, that is, the cost of the development and the property, as fixing very largely the cost of producing the power. It is quite common to have labor and supplies cost not more than $1 per kw-year, but this would not be considered as representing the cost of the power. Where a chemical industry owns the hydroelectric power plant as well as the chemical works, the foreign practice is inclined to consider the investment as a whole and apportion the costs of operation to the various departments, while interest on the capital is charged to the profits. The costs of producing power are therefore uniformly much lower than we are accustomed to figure on. There are many plants in operation in the chemical industries abroad whose real costs of producing power are no lower than many of the more favored locations in this country.

"Off-Peak Loads.—One of the chief interests in the chemical utilization of electrical energy is centered in the possibilities of off-peak or off-season loads, as American plants generally have a certain proportion of power which can be disposed of to better advantage than selling the entire output as low priced power to chemical industries. This off-peak power is difficult to utilize in furnace work, where the cooling of the furnace and its charge is an important factor, both from the standpoint of cost and of output, and again adjustments may be so disturbed from an interrupted output as to be absolutely impracticable. One of the possible solutions for off-peak utilization appears to be in the adoption of some system where fuel is also utilized and the

radiation losses are not excessive under conditions of banked fire when the electric portion of the heat energy is not in use. Some of these combination processes may promise a solution of the off-peak load situation more attractive than the straight electric furnace, which is difficult to cool down entirely without unduly affecting the conditions. In all plants the volume of output is the determining factor in absorbing the general overhead charges, and any intermittance must diminish output with its accompanying disadvantages.

"If the furnace could be operated on the off-season load and its product stored, and the chemical works utilizing this product could operate on a normal schedule, this would form one solution; or another would be if by chance the off-season power were available at the time the greatest demands were to be met, such as preparing a fertilizer product at the season of fall rains for the early spring delivery. All of these plans, however suggest the necessity of operating at least a portion of the plant continuously in order to meet fixed charges and preserve an operating organization. If the chemical works requires a moderate amount of power for its processes in year around operation and only its surplus for manufacturing its crude material at the off season peak it promises the greatest possibilities."

Mr. Summers concluded that the future of nitrogen fixation is alluring and promises many developments along lines other than those considered, but already the market has felt the effects of these various processes and instead of nitrogen being figured at 13 cents per pound, it is confidently predicted it will very shortly find its level at a selling price of about 8 cents, making a cost of production of 5 to 6 cents per pound and thus reducing sodium nitrate to about 1.33 cents per pound, or approximately $30 per long ton, and the lower grade mines will feel this and be forced to curtail.

The Cyanamid Process

The second paper of the evening was presented by Mr. **Frank S. Washburn**, president of the American Cyanamid Company, on the cyanamid process. As this paper is to be called up for discussion at the general meeting of the American Electrochemical Society in Atlantic City in April, we reserve a full report of the paper for our next issue and will give here a short abstract only.

In his paper Mr. Washburn pointed out that while the industries of the fixation of atmospheric nitrogen are only ten years old, they have reached a great commercial importance. The annual productive capacity of the existing plants employing the "arc" and "cyanamid" processes is between 90,000 and 100,000 net tons of fixed nitrogen, which, at the normal average value of the product at the factory door, represents $25,000,000. This is divided in the ratio of two-thirds to "cyanamid" and one-third to the "arc" process. The American Cyanamid Company's factory at Niagara Falls, Canada, has alone a capacity in fixed nitrogen approximately half as great as the total world's installed capacity by the "arc" processes.

Mr. Washburn then took up the economic aspects of nitrogen fixation on the North American Continent. Nitrogen is used largely for three purposes: For crop fertilizer, for the production of nitric acid and its derivatives and for the production of ammonia. Nitric acid is relatively a small business, as great industries go, The fertilizer industry, on the other hand, is of immense importance.

Mr. Washburn pointed out the necessity of increasing crop yields without additional labor—that is, by the use of artificial fertilizers. European yields per acre cultivated are 50 to 100 per cent greater than American yields. The use of fertilizers in Europe per acre cultivated is enormously greater than in America. The average increase in yield in Germany for the past twenty years has been approximately 60 per cent, in the United States 20 per cent. Abroad this increase is attributed to intensive farming, better selection of seed, the rotation of crops, and, to the extent of 50 per cent to 70 per cent of the increase, to the use of commercial fertilizers.

Mr. Washburn emphasized that if the American farmer is to use more fertilizer nothing is more important than to place at his disposal a high-grade chemical salt containing nitrogen and phosphorus, well balanced and in large percentages, and possessing in a high degree the many requisites of a good fertilizer, such as being non-hygroscopic, non-toxic, finely granular in form, non-leachable in the soil and readily convertible by nature's forces into the organism of the plant.

The author gave considerable data on comparative costs of the various atmospheric nitrogen fixation processes and their prospects in the United States. He thinks that the arc processes will be restricted to nitric acid field and it will not pay them to go into the nitrate business. On the other hand, the ammonia processes may go into the nitric acid field. The author's argument tended toward the conclusion that the cyanamid process seems destined to play the leading role in the fixation of atmospheric nitrogen in the United States. Unique in air nitrogen fertilizer processes is the direct and valuable application of the raw product cyanamid, as is proven by the fact that fully 80 per cent of the entire annual product of normally $15,000,000 value is sold as the raw product. But there is also a long list of promising derivatives, ammonia, urea, cyanides and argon (used in the lamp industry).

Discussion

The discussion was opened by Dr. J. W. Richards, who reviewed the great progress made in recent years, but emphasized the "wonderful inefficiency" from the thermal and energy standpoint of all processes for the fixation of atmospheric nitrogen. The thermal efficiency of the nitric-acid arc process is only about 1.4 per cent, while the cyanamid process fixes about twice as much atmospheric nitrogen per kw-hour. There is a wide margin for improvement.

Mr. J. L. R. Hayden, in a communicated discussion, said that a series of experiments in Dr. Steinmetz's laboratory with arcs of different temperatures (produced by using different electrode materials, iron, titanium, carbon and copper) showed no direct relations of the NO concentrations to the arc temperature. He considers that the essential phenomenon in the arc is the dissociation of the oxygen and nitrogen molecules into N atoms and O atoms, which pass out of the arc and combine with each other according to the probability law.

Mr. D. B. Rushmore emphasized that our civilization is absolutely founded on the layer of from 4 to 6 in. of soil on the surface of this earth, and the conservation of this layer is an absolute necessity, and we have still very much to learn on fertilizing. He suggested the possibilities of development of water powers in agricultural districts and asked as to the effect of the electric field in arc processes.

Dr. C. A. Doremus referred to a treatise published in 1802 by Felix Pascalis, in which he referred to the possibility of manufacture of nitric acid from nitrogen of the air according to the expectations of Citizen Guyton. It has required a world conflagration to make us in this country appreciate our possibilities.

Mr. F. V. Henshaw asked as to the requirements of geographical location of nitrogen fixation plants.

Mr. Washburn replied that for pure cyanamide factories interior water power plants serving adjoining agricultural districts would do, but for the manufacture of ammonia-phosphate fertilizers cheap water transportation is as necessary as cheap water power. He said, however, that the beef-packing business was successful in spite of very large shipping bills, and a great nitrogen industry will be also able to face successfully similar handicaps. But this means manufacturing at one point on the largest scale.

Mr. Summers, in closing, said in reply to Mr. Rushmore's last question that at the high temperature of arc processes dissociation is so active that though there was an electrical effect it would be overcome and the final effect is purely thermal. Ozone, on the other hand, is produced at low temperature.

Chemical Reactions at Low Pressures

On the evening of Friday, March 5, in a meeting of the New York Section of the American Chemical Society, held in the Chemists' Club in New York City, the Nichols gold medal was presented to Dr. IRVING LANGMUIR, of the Research Laboratory of the General Electric Company, Schenectady, N. Y., for his research work on chemical reactions at low pressures.

IRVING LANGMUIR

The presentation of the medal to Dr. Langmuir was made by the chairman of the Section, Professor Allen Rogers, in a felicitous little speech. Dr. Langmuir, in expressing his thanks, modestly laid great stress on the help and co-operation he had had in his research from others. Dr. Langmuir then presented a long formal paper on "Chemical Reactions at Low Pressures," of which we herewith give a brief abstract.

In the course of the author's investigations into the causes of the blackening of tungsten lamps the effects produced by the introduction of low pressures of various gases were studied in considerable detail. It had been previously known that the vacuum in a lighted tungsten lamp normally improves during the life of the lamp, but it was thought that this removal of the residual gases was brought about by electrical discharges in much the same way as that commonly observed in Geissler and Roentgen ray tubes. These experiments have shown, however, that a highly heated tungsten filament will cause the disappearance or clean-up of nearly any gas introduced into the bulb at low pressure, and that this action, in the great majority of cases, is purely chemical in nature.

The experimental methods that were employed in these investigations are relatively simple. A bulb containing one or more short filaments, usually the tungsten, was sealed to an apparatus consisting essentially of a mercury Gaede pump, a sensitive McLeod gage for reading the pressure, and an apparatus for introducing small quantities of various gases into the system and for analyzing the gas residues obtained in the course of the experiments.

By means of the pump the pressure in the system could be lowered to 2/100000 of a mm of mercury. The McLeod gage gave a reading of 1 mm on the scale for a pressure of seven millionths of a millimeter of mercury. By means of the apparatus for analyzing gas, a quantitative analysis of a single cubic millimeter (at atmospheric pressure) of gas could be carried out, determining the following constitutents: Hydrogen, oxygen, carbon dioxide, carbon monoxide, nitrogen and the inert gases.

In a typical experiment, after having thoroughly exhausted the whole apparatus, a small quantity, usually 5-20 cu. mm of gas, is introduced and the filament is electrically heated to a definite temperature, while readings of the pressure are taken at regular intervals (usually one minute). By plotting the pressure readings against the time, a curve is obtained which clearly shows how the rate of clean-up varies with the pressure.

In this way the author studied the clean-up phenomena with many different gases and several different kinds of filaments. Most of the work was done with tungsten filaments, but in order to get a broader outlook over the field of low pressure reactions, filaments of carbon, molybdenum, platinum, iron, palladium and other metals were also tried. The principal gases studied were oxygen, nitrogen, hydrogen, carbon monoxide and dioxide, chlorine, bromine, iodine, methane, cyanogen, hydrochloric acid, argon, phosphine and the vapors of many substances, such as mercury, phosphorous, phosphorus pentoxide, sulphur, etc.

With each of these gases, conditions could be found under which a heated tungsten filament will cause the clean-up of the gas. The curves obtained in the course of the experiments furnished very complete data for a study of the kinetics of the reactions involved.

Dr. Langmuir points out that the study of gas reactions affords the best means of studying the reaction mechanism, and that by the use of extremely low pressures the experimental conditions are enormously simplified. The reaction velocity is then much more intimately related to the behavior of the individual molecule than it is at higher pressures. The reaction velocity becomes a matter of statistics. The question is: Out of all the gas molecules which strike the surface of the heated filament, what fraction will enter into reaction with it?

Dr. Langmuir's researches related to reactions between gases and heated filaments, that is, heterogeneous reactions involving a solid and a gaseous phase. Comparatively little work has been done in the past on heterogeneous reactions.

It was at first thought that the law of mass action could be applied to heterogeneous reactions just as to homogeneous reactions. Experiments soon showed, however, that other factors than purely chemical ones usually determined the velocity of these reactions. Noyes and Whitney (*Zeit. Physik. Chem.*, vol. 23, p. 689, 1897) studied the rate of solution of solid substances in liquids and concluded that the velocity was dependent entirely on the rate at which the dissolved substances could diffuse out through the thin layer of liquid next

to the solid. Stirring the liquid had the effect of thinning this layer and so increased the rate.

Nernst extended this idea and suggested that the velocity of heterogeneous reactions in general was limited by the rate of diffusion of the reacting substances through a "diffusion layer," which he considered, under ordinary circumstances, to be of constant thickness. Thus he reasoned that the velocity of these reactions in practically all cases should be proportional to the concentration of the reacting substances. In other words, the reactions should follow the laws of monomolecular reactions. Nernst pointed out, however, that it was wrong to draw conclusions as to the mechanism of heterogeneous reactions from velocity measurements.

Dr. Colin G. Fink (Dissertation Leipzig 1907: see also Bodenstein and Fink, *Zeit. Phys. Chem.*, vol. 60, p. 1, 1907), as a result of his study of the kinetics of the sulfur trioxide contact process, developed a theory of the mechanism which marked a new step in our conceptions of the mechanism of heterogeneous reactions. Bodenstein and Fink (*Zeit. Phys. Chem.*, 60, 46, 1907) successfully applied this theory to a large number of other catalytic reactions.

This theory differs essentially from Nernst's in that the rate of diffusion of the reacting bodies through an *adsorbed film* of *variable thickness*. Thus, in the case of the reaction $2\ SO_2 + O_2 = 2\ SO_3$ in contact with platinum there is present on the platinum an adsorbed layer of SO_3. The theory assumes that the thickness of this layer is at all times proportional to the square root of the concentration of SO_3 in the gas phase; in other words, that there is an adsorption equilibrium. The reaction is assumed to take place only at the boundary between the adsorption film and the platinum. The oxygen and sulfur dioxide must therefore diffuse through the film before being able to react.

This theory seems to have met with general favor and has been applied to the kinetics of many heterogeneous reactions. Dr. Langmuir proposes to modify Fink's theory slightly in that he assumes the reaction velocity to be limited not by the rate of diffusion through the adsorbed film, but rather by the rate at which the surface of the metal becomes exposed by the evaporation of single molecules from an adsorbed layer one molecule deep.

Dr. Langmuir gave in his paper a concise review of some of the fundamental principles of the kinetic theory of gases and followed this by pointing out the essential differences in his low-pressure experiments with filaments, and the conditions that would prevail if higher pressures were used.

At pressures as high as atmospheric pressure, convection currents set up by the filament produce very serious complications. At pressures of a tenth of a megabar* or less, convection currents become negligible for most purposes, but the problem is still complicated by the sharp temperature gradients that occur in the gas around the wire. At ordinary pressures, unless the velocity of the reaction is extremely small, the rate of reaction is determined largely, if not wholly, by the rate at which the reacting substances can diffuse to the surface and the products diffuse out. Under these circumstances, we should expect Nernst's theory to apply in general, but in this case we are really not measuring the velocity of a chemical reaction at all; we are merely measuring a diffusion coefficient in a gas.

On the other hand, at pressure as low as 10 bars diffusion may be considered as practically infinitely rapid. At this pressure the free path of the molecules of most gases is very close to 1 cm. This is so large, compared to the diameter of the wire, that it is evident that the molecules leaving the wire can in no way interfere with those approaching it. Under these conditions the gases don't need to diffuse through each other in the ordinary way. At such low pressures as those we may, in fact, look upon the gas as consisting of a swarm of molecules entirely independent of one another.

The velocity of the molecules around the filament is then determined by the temperature of the bulb and is entirely independent of that of the filament. There is thus no temperature gradient in the gas around the filament. The average velocity of the molecules striking the filament is definitely known, and in case two or more gases are present, the relative number of each kind of molecules striking the filament is also known, no matter how rapid the reaction may be.

An interesting feature, possible only with reactions at very low pressures, is the fact that the temperature of the molecules striking the filament is different from that of the filament itself. At ordinary pressures, because of the heat conductivity of the gas, the molecules striking a solid body are, of course, always at the same temperature as the body itself. This opens up new possibilities in studying the kinetics of reactions. The effect of separate variation in the temperature of two reacting substances can thus be studied. If it is the impact of the gas molecules against the surface of the filament which determines the velocity of the reaction, then this velocity should depend much more on the temperature of the bulb than on that of the filament, since the impact depends on relative velocity, and the velocity of the heavy tungsten atoms, even at high temperatures, is much less than that of ordinary gas molecules at room temperature. On the other hand, if the reaction velocity is determined rather by some condition of the surface of the filament, then the effect of bulb temperature will usually be negligible.

Another result of the use of low pressures is that the molecules of the products of a reaction, when they leave the filament, do not return again until after having made many collisions with the bulb. If the substance formed is a non-volatile solid, or can be condensed by cooling the bulb in liquid air, it is thus possible to make certain that the reaction does not take place as the result of two collisions, but necessarily occurs in one. In this way also it should be possible to produce many compounds which are very unstable at the temperature of the filament.

At sufficiently low pressure (about 1 or 2 bars) the molecules leaving the filament travel directly to the bulb without striking any other molecules on the way. Naturally, they have no chance of giving up any energy on the way to the bulb, and therefore (if we can speak of the temperature of a single molecule) reach the bulb with the same temperature as that with which they left the filament. This must give the most sudden cooling which it is possible to give, and there is then the minimum chance for the decomposition of the product formed if it happens to be unstable at some temperature between that filament and bulb.

Another important advantage in working at low pressures is that the velocity of even the most rapid reactions in this way can be slowed down sufficiently so that they can be studied quantitatively. The heat liberated by the reaction on the filament is usually so small as to be noticeable, or at any rate is not so large but the isothermal conditions may be maintained.

After his exceedingly interesting general exposition of what may be learned from the study of gas reactions at extremely low pressures, Dr. Langmuir discussed in detail the reactions which occur when a gas is "cleaned-up" by a heated filament. We can give here only a very brief summary of these parts of Dr. Langmuir's paper.

*1 bar = 1 dyne per sq. cm. 1 megabar = 1,000,000 bars and almost exactly = 750 mm. of mercury.

There are four classes of cleaning-up reactions.

(1) *The filament is directly attacked by the gas.*—A typical example is the clean-up of oxygen by a tungsten filament (*Journal* Am. Chem. Soc., vol. 35, p. 105, 1913). This reaction is interesting in its bearing on the theory of molecular films. Reactions between chlorine and tungsten and between carbon and oxygen were also discussed, but more briefly, under this heading.

(2) *The gas reacts with the vapor given off by the filament.*—The reactions discussed by Dr. Langmuir under this heading were the clean-up of nitrogen by a tungsten filament (*Journal* Am. Chem. Soc., vol. 35, p. 931, 1913) and by a molybdenum filament, the clean-up of carbon monoxide by tungsten, and the clean-up of oxygen by platinum.

(3) *The filament acts catalytically on the gas, producing a chemical change in the gas without any permanent change in the filament.*—A typical example is the dissociation of hydrogen into atoms in contact with a tungsten wire at low pressure (*Transactions* Am. Electrochem. Soc., vol. 20, p. 225, 1911; *Journal* Am. Chem. Soc., vol. 34, pp. 860 and 1310, 1912; vol. 35, p. 927, 1913; vol. 36, p. 1708, 1914, and vol. 37, 1915). The dissociation of the hydrogen does not occur in the space around the wire, but takes place only among the hydrogen molecules which have been absorbed or dissolved by the metal. Other examples of catalytic reactions discussed by Dr. Langmuir are the dissociation of chlorine into atoms, the dissociation of oxygen into atoms, and the reaction between carbon monoxide and oxygen in contact with platinum.

(4) *The gas is chemically changed, or is made to react with the filament by means of electric discharges through the gas.*—If a positive potential of 100 volts or so is applied to an auxiliary electrode in a bulb containing a heated filament, electrons are given off from the heated filament and these, in passing through the gas, may produce ionization. The positive ions then are attracted to the hot filament and strike it with high velocity. Under these conditions reactions often occur which otherwise would not take place. For example, if the gas is nitrogen, these positive ions will combine with the tungsten filament to form the nitride WN_2 even at temperatures where there is normally no appreciable volatilization of the tungsten.

In the reactions considered by Dr. Langmuir the velocity of the reaction is limited by the rate at which the reacting molecules come into contact with each other.

With reactions occurring on the surface of the wire, only a small fraction of the surface was in condition suitable for the reaction. The rate of reaction in these cases was limited by the rate at which the gas molecules could strike that part of the surface where the reaction could occur. In no case was there any evidence that the reaction was limited by any diffusion process in the ordinary sense.

In the case of reactions where the gas combined with vapor from the filament, the rate was again limited by the rate at which the molecules came in cantact. All those that made contact reacted.

Only in two cases was it possible to measure a velocity which was not limited by such purely physical factors. These cases were the combination of nitrogen with molybdenum vapor and the attack of tungsten filament by carbon monoxide with low bulb temperatures. It is remarkable that in both these cases the temperature coefficient of the reaction velocity was strongly negative. In all the other reactions the large positive temperature coefficient was due to the fact that the rate of evaporation of the filaments or of absorbed materials on them increases so rapidly with temperature.

Dr. Langmuir did not mean to imply that all truly chemical reactions must have negative temperature coefficients, but the results strongly suggest that such chemical reactions are very common, but that their effects are masked by other physical factors having large positive temperature coefficients.

The number of chemical reactions previously known which have negative temperature coefficients is extremely small. Bodenstein cites one case, while Strutt found that atomic nitrogen recombines to form molecules much more rapidly at low temperatures than at high, and reasoned that a high translational velocity of the molecule should in general hinder rather than hasten the reaction. Strutt considered that rotational velocity of the molecules, on the other hand, favors the reaction and that this factor in the majority of reactions greatly outweighs that of the translational velocity. Thus reactions between atoms should always have negative temperature coefficients, since atoms cannot have rotational energy. Dr. Langmuir's work lends further support to Strutt's views.

The viewpoint developed as a result of this work with low pressure reactions is undoubtedly applicable to reactions at high pressures and also to reactions between solids and liquids. Dr. Langmuir expressed the hope that further work will lead in a similar way to a better understanding of the mechanism of homogeneous reactions.

The Proposed British Dyestuff Industry

A German Opinion on Great Britain's Prospects

In view of the serious attempts which are being made at present in Great Britain to create a British dyestuff industry, it is of particular interest to read what a prominent representative of the German chemical industries has to say about these endeavors.

In the *Chemiker Zeitung* of Feb. 13, 1915, Dr. Otto N. Witt, who is professor of applied chemistry at the Charlottenburg Institute of Technology and who was employed in former years as a chemist of some British aniline-dye works, publishes an article on "The New English Dyestuff Industry," which we reproduce slightly abstracted in translation:

"The desire to develop a strong and complete coal-tar industry, the most important branch of which must be the manufacture of dyestuffs, is not only comprehensible but logical and natural in every country which owns large coal fields and has an extensive iron industry. Such a country is bound to install by-product coke ovens and will, therefore, find it necessary to make profitable use of the abundant quantities of the tar.

"It is also easy to understand that during the present war, when the interchange of products between nations becomes difficult and frequently impossible, the lack of a coal-tar industry makes itself more felt than in days of peace, when a highly organized shipping trade meets every demand. Thus it has happened that not only Great Britain, but also the United States of America, have been thinking of the establishment of a coal-tar industry.

"In both countries these efforts would have been made at an earlier date were it not for the fact that for many years an entirely unjustified prejudice against cooking in by-product ovens had existed, which only recently has been overcome.

"If, therefore, the desire for a coal-tar industry in England and in the United States is something that was to be expected in the course of natural development, neverthless, it is grotesque that in the case of England this development is an outgrowth of the national idea that Great Britain has been harmed by Germany's technical development, although the latter was but a natural

development of a healthy, well-governed people with the will to live. . . .

"In many publications I have pointed out that no country is able to transplant the technical creations of another country as a whole. Therefore I hardly think that England's present efforts to establish a dyestuff industry after the German model will be a success. I will try to give the reasons for this opinion.

"I have formerly shown that the color industry has never been developed in England to any great importance, although it was started there under the most favorable conditions. For many years England had a monopoly on all coal-tar products; besides, by the war of 1870-71, she had become free from all competition in the dyestuff industry, so that she had the best opportunity for getting such a strong foothold among the consumers in the whole world that it would have been difficult to compete against her. From the chemical point of view the dyestuffs, although not numerous, which at that time were made in English works were absolutely equal to the products of continental Europe, as I know from my own experience.

"If some of the processes of manufacture were somewhat cumbersome, according to our present views, this was also true in many instances on the Continent, while at the same time the prices, even with expensive processes of manufacture, left a sufficient profit. The nature of these processes frequently depended on local conditions. As an instance I mention the manufacture of the fine alcohol blues. In the Swiss works they were made by repeated extraction of the crude blue by alcohol which at that time was exempt from taxes in Switzerland. In England, where always a high tax was levied on alcohol, an ingenious process was used, by which the blue base was dissolved in aniline oil; an equivalent quantity of aniline salt was then added, whereby the chlorhydrates of the triphenylrosanilines were formed. Of these that of the fine blue is quite insoluble in aniline; it therefore crystallizes out of the solution in magnificent leaves, glittering like gold, while the ordinary blue was recovered from the motherlye by driving the aniline over with steam. In this manner and without the use of alcohol, although with the use of a solvent expensive at that time, such a complete separation of the two blues was accomplished in one operation that even to-day I would prefer this process above any other, if, perhaps for scientific purposes, it was necessary to completely separate the mixture of dyes resulting from introducing the phenyl group into ordinary rosaniline. In the industry, to be sure, the demand for a good light blue has been filled in a simpler manner by the use of pararosaniline, but this was accomplished only several years later.

"If, therefore, ability can not be denied to the older English color industry why has it accomplished so little? To this the English of to-day have the easy answer that the German competition has been the cause. But the unbiased observer will contend that of two competitors the one who was first on the spot and worked under more favorable conditions has the advantage. This was undoubtedly England. What was her shortcoming?

"Not one but several causes have acted together to bring about the result. One of them has been discussed to distraction on both sides of the Channel. It is the co-operation of scientific research with the industry. The English chemists, who are not numerous, but some of whom are very prominent, have emphasized this point in order to advocate an increase of their scientific and research laboratories. They conclude by way of inference that England, if provided with as many scientific laboratories as Germany would produce as large a number of well-trained chemists for her industry as Germany does. They overlook, however, that it does not suit the character of the young Englishman to be trained to be a scientific assistant in the same manner as the German student who, owing to the system of examinations and promotions, is obliged for a time to do independent research work before he can think of earning his daily bread. Many a student would perhaps not do the former if he were not compelled to. After, however, he has gone through this wholesome training the acquired scientific habit will mostly stay with him during his later professional life. That is, if we want to be quite frank, the true reason for interrelation between science and industry in Germany. If we had to rely only on those who have been born with a desire for research work, the number of scientific assistants in the German industry would not be as large as it actually is.

"It might be said that Germany has established also in her industry a general compulsory service (the English call it "militarism") which bears such brilliant results in her army. Not every soldier can be a strategical genius. In the same way the great majority of the thousands of capable and reliable chemical engineers, whom Germany has at her disposition, do not claim to perform original and inventive work. They are quite content with the rôle of intelligent and reliable factors in a great system created and more and more developed in the course of time by the genius of a few organizers, which, once created, is self-maintaining and produces its own leaders as in a well-organized military power. It would be a pity if in our educational courses and in our professional work we were lacking this strict organization. The situation would then be as it is in England, where every young man from his sixteenth or seventeenth year thinks of earning a living and if he does not his parents or relatives will make him understand that that is the proper thing for him to do. In Germany there are thousands of fathers who starve so that their sons might have a college education; these are unknown in England. There it is the privilege of the well-to-do "upper ten thousands" to send their sons to the universities, at the same time giving them such large allowances that the young men are in a position to spend more of their time on expensive sport than on scientific work. As a consequence, the scientific institutes of the universities and especially their chemical laboratories must be called poorly equipped from our point of view. What they have is all that is necessary to keep up the style of the English universities as it is fixed by traditions of centuries.

"Those laboratories in England which are not quite as narrowly framed as the national universities proper and which enjoy more freedom are few in number, but they are the real cultivating grounds of chemical science in England. They serve the requirements of those who have an inborn desire to devote themselves to research work and who have the means to do so. But as the means are often lacking, nearly all of these institutions have so-called "evening classes," in which for a modest remuneration such people can partake whose day-time is taken up by their trade, but who have nevertheless a desire for scientific studies. That these courses are in many instances very thorough must be mentioned with praise, but it is evident that they cannot give advanced instructions for experimental work, not to speak of independent research work.

"These conditions are the reason that the English nation, perhaps more frequently than the German, has produced able, occasionally even ingenious, autodidacts in chemistry (I only mention Gilchrist Thomas), but they are also responsible for the fact that the great army of all-around useful, scientifically well-trained as-

sistants, as Germany has, to the good fortune of her industry, is entirely missing in England.

"It is not impossible that in England these conditions may change as completely as has been the case with some other things. Such a change is, however, as little probable as is the overcoming of two other evils in the color industry.

"From a technical point of view, the English industry has suffered from a lack of organization and of working records. This evil is connected more closely than may appear at the first glance with the lack of scientifically trained assistants. The English factories must, in many cases, entrust with the management of their works people who belong not even to the "semi-educated class," although they are frequently very handy and intelligent. As a natural consequence the working records in some instances are limited to chalkmarks. The more manifold a manufacturing process, the more dangerous is the lack of control.

This may perhaps have been remedied in some works, since the Americans have raised the control system to a kind of science, mainly in machine shops, and have thereby directed the attention of larger classes to the importance of scientific management. Nevertheless I doubt whether the greater number of the works of the English chemical industry have an organization which can be compared to that in most German plants. For the German works organization has been created chiefly by the talent of a few scientifically trained chemists who managed to permeate even the dry array of figures with the live spirit of investigation.

"Finally it was the insufficient commercial organization that was the greatest detriment to the older English color industry. This shortcoming has been openly and frequently admitted by the English themselves for other branches of industry, and there have always been people in England who have recommended to their countrymen to take as a model the activity and circumspection of the German businessman. But they evidently have often preached to deaf ears.

"We [the Germans] are accustomed to look upon the English as very able businessmen. They certainly are as far as the spirit of enterprise, far-sightedness and large commercial speculations are concerned. But the English are less fit for the organization of a trade which, like the sale of dyestuffs and of fine chemical products generally, requires that continuously all small details are observed without losing sight of the great viewpoints. For this purpose the many Germans who heretofore used to earn their bread in England have been useful members of the English commercial world and their absence will be seriously felt when, after the war, they are released from the detention camps and leave England.

"In the foregoing I think I have enumerated the most important reasons why the older English color industry, though started under the most favorable auspices, failed to keep step with the younger Germany industry and, in spite of all the beautiful speeches, has been forced more and more to the background. According to the English view, these are mere details. The new industry is to be started with the aid of the Government which is to advance some millions, for the larger part of which, however, the consumers of the new dyestuffs are to be held responsible.

"How about these dyestuffs? That they will leave nothing to be desired is, according to the English view, warranted by the names of the members of various committees which have been formed for the organization of this affair. Very many of these members I know personally well. These gentlemen, mostly well advanced in years, none of whom has so far been prominently active in the color industry, will hardly be able to build a large factory and to manage it. In addition there are in the committee several, probably younger men, whom I do not know and among whom there are probably those organizing talents who now, all at once, shall stamp out of the ground what England for more than fifty years has in vain cried for and aimed at—a great organic chemical industry, strong enough to compete against the German industry in England and in the world's markets, and at the same time able to pay interest on the capital advanced for its foundation.

"In the latter point, which must not be forgotten, there lies the greatest difficulty of the whole enterprise. All the others may be overcome with the aid of an exceptionally favorable chain of circumstances. Whether the government or the textile industry of England advances the required large capital neither one nor the other can waive an adequate interest and amortization. This means that 12 to 15 per cent of the capital invested must be earned before any profit can be made. If we consider that every new enterprise has its infancy losses, that not only the new factories but in many instances also the conditions for their existence have to be created, no favorable prognosis can be made for a profitable development.

"The German and Swiss color works have accumulated in the course of many decades not only large reserves by most cautious and rational financing, but they have also written off the book value of their plants to a minimum. This ensures a continuous source of profit which is lacking for every new enterprise of the same kind. For this reason the founding of new color works, formerly so popular, has been discontinued in continental Europe entirely. Every financier to whom such a scheme would be proposed would immediately realize that the new enterprise would not be able to compete against the old large works. But England wants to make the experiment, after having heretofore always complained that her existing color works cannot exist against the German competition. If these factories had been managed chemically, technically and commercially in the right manner and if they had accumulated reasonable reserves they would have worked under nearly the same conditions as the German ones. Like these, they could have expanded long ago to very large enterprises which could have met the German competition under equal conditions. As they have not accomplished this, a new large enterprise is now to be founded, which under worse conditions is expected to achieve the success that was denied to the old works.

"Success of this undertaking could leave Germany, of course, entirely disinterested if it would not bring about certain very remarkable consequences. Not so much for the German color industry, which may be confidently relied upon to meet the new competition, but in the first place for the German textile industry. It cannot be denied that in a large number of products, and especially in those which by their higher value left a greater margin for clear profit to be realized, as fine worsteds and other woolen cloths, fine-filed cottons and linens, the German industry has not been equal to the English, as is evident from the import statistics. Just this English industry has heretofore largely used German dyestuffs, and just this industry is supposed to finance the new English color industry, or, in other words, to bear the unavoidable damage which it is bound to do. That means, of course, a weakening of this heretofore strongly founded English textile industry and consequently a strengthening of the German one. The latter must and will under all circumstances, after the war, strive to produce for the home market many articles which heretofore were bought from England, and the

total value of which probably balances the value of the chemicals exported from Germany to England. It can do so the more readily as long as England harms and cripples the exporting part of her own industry by new enterprises which are not created in a rational, commercial spirit, but which are the offspring of the passions of envy and of jealousy. For the German color industry the result will be that it will be able to dispose of a large part of what it has heretofore exported to England in the home market due to the expansion of the German textile industry.

"The whole affair reminds one very vividly of the famous 'Made in Germany.' The demand for this inscription on all German goods was a measure dictated by jealousy and based upon the supposed inferiority of the German products, which inferiority was so long talked of in England that it finally was believed. To-day it is generally known that the strict observation of this measure has furnished uncounted millions to the German trade. I can see no reason for any apprehensions on the part of Germany about the creation of the new English color industry."

Recent Chemical and Metallurgical Patents

IRON AND STEEL

Interlocking Brick for Hot-Blast Stoves.—In Fig. 1 is shown a form of interlocking brick for hot-blast stoves, patented by EDWIN E. SLICK, of Westmont Borough, Pa. The idea is to provide a brick which cannot become broken, shifted or thrown out of alignment due to the extreme changes of temperature which occur in such stoves, and the sudden blasts or explosions which sometimes occur. The drawing at the left of Fig. 1 shows a top plan view of a portion of brick work as constructed of the interlocking bricks, which are shown in plan and elevation at the upper and lower right respectively. (1,130,031, March 2, 1915.)

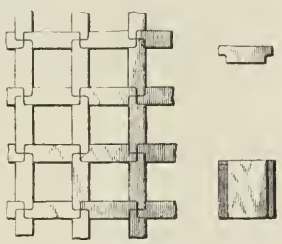


FIG. 1 — INTERLOCKING BRICK FOR HOT-BLAST STOVES

Alloy for Dynamo-Electric Purposes.—A patent of WALTER RÜPEL, of Westend, near Berlin, Germany relates to a process of manufacturing an alloy of iron technically free from silicon, phosphorus and manganese, and of a corresponding admixture of copper. The process consists in deoxidizing purified and superoxidized iron by means of a small quantity of alkali-earth metal added in the form of an alloy with copper. For example, calcium, equal to 4 per cent of the copper to be used, may be added in the form of an alloy with copper. The result will be an iron almost free from Si, Mn, P and C. (1,130,678, March 2, 1915.)

Plating or Galvanizing Machine.—Apparatus for plating or galvanizing structural bars, pipe and other objects of considerable length, is patented by CONSTANTINE G. MILLER, of Chicago, Ill., the patent being assigned to the Meaker Company. Previous attempts to galvanize angles and channels have been unsatisfactory for the reason that the gasing of the electrolyte permits an accumulation of hydrogen bubbles beneath the cavities of the bar, and thus prevent uniform plating. The present apparatus consists of a tank or trough through which the pieces to be galvanized are passed. The treatment is designed to be continuous and to yield uniform plating. The pieces to be treated are delivered into the machine on cathode bars, above and below which are supported suitable anodes. Mechanical means are provided for transporting the pieces through the trough, and also for periodically turning them over so that accumulations of hydrogen are prevented. The agitation of the electrolyte, as well as the shock of the blow in turning the piece, serves to displace gaseous bubbles, keeping the plating surface clean. (1,128,481, Feb. 16, 1915.)

Gold and Silver

Vacuum Slime-Filter.—Apparatus adapted to filter ore-slime in the cyanide process, shown in plan and sectional elevation in Figs. 2 and 3, respectively, is patented by CHARLES G. OSGOOD, of Tonopah, Nevada. The patent is assigned to the Montana-Tonopah Mines Co. In general plan and method of operation the apparatus

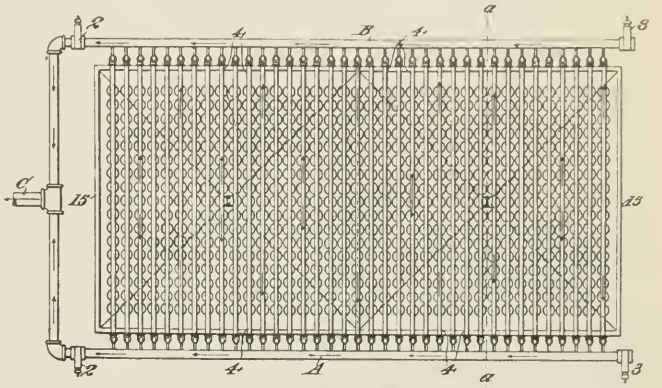


FIG. 2—VACUUM SLIME FILTER

resembles the stationary-leaf type of filter, with a large number of filter spikes substituted for leaves. Referring to the figures, the spikes 5 are supported from cross headers 4, which are all connected with manifold pipes A and B. The manifold pipes join at C and are in connection with a suitable pump, not shown. The entire filtering apparatus is contained in a tank 15. The spikes are formed with a tapered core of rectangular cross-section and having longitudinal corrugations on the sides, and a filter fabric enclosing the core. The inventor claims superiority over the leaf-type of filter in capacity per unit of space, economy and convenience of operation, and adaptability to various applications.

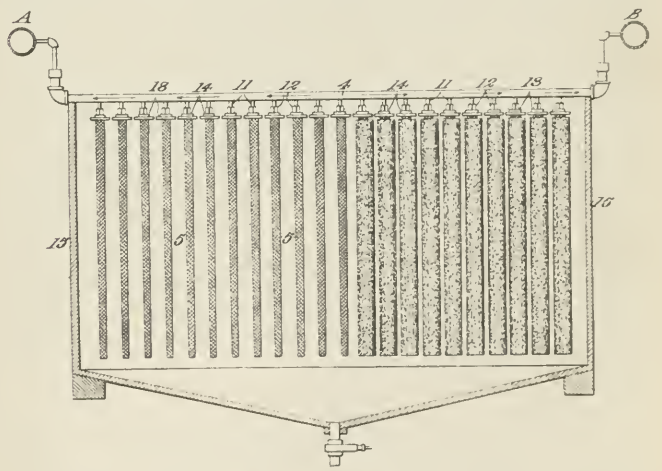


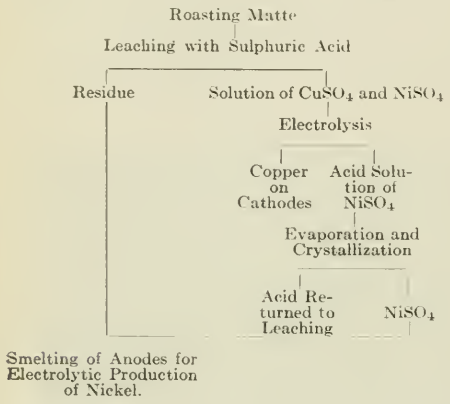
FIG. 3—VACUUM SLIME FILTER

It is further claimed the invention obviates certain difficulties encountered in leaf filters, such as unequal building of the cake, breaking and fracturing of the same, and cleaning of the filter leaf. (1,128,495, Feb. 16, 1915.)

Copper, Nickel and Zinc

Refining Copper-Nickel Matte.—In several patents recently granted to N. V. HYBINETTE, of Christiania,

Norway, the inventor discloses improvements on his method of refining copper-nickel matte which was noted in this journal, January, 1906. According to that process the matte was roasted, leached to remove excess of copper, smelted and cast into anodes and also into slabs for cementation of copper from the electrolyte containing copper and nickel in the form of sulphates, thereby regenerating the electrolyte in nickel, the copper replacing the nickel in the slabs. The process of producing the copper-nickel anodes is shown below.



The anodes thus produced are electrolyzed in an acid nickel sulphate solution, whereupon copper is cemented out from the solution on metallic slabs. A special form of cell is provided for this part of the operation. The inventor previously prescribed copper-nickel free from sulphur, carbon and silicon as the material for the metal slabs on which to cement the copper. He has now discovered that cementation is possible on slabs of copper-nickel containing 4 to 8 per cent sulphur, cast from a blast furnace, provided that the slabs have been used previously as anodes in a nickel-plating tank, thereby preparing their surfaces in such a way that cementation will take place. (1,128,313-4-5-6, Feb. 16, 1915.)

Removal of Cadmium from Zinc Ores.—According to a patent granted to Gilbert Rigg, of Palmerton, N. J., and assigned by him to the New Jersey Zinc Co., cadmium can be removed from zinc ores by leaching the ore with water containing sulphuric acid in sufficient amount to convert the cadmium oxide to sulphate. Even when the sulphuric acid radical is already combined with zinc as zinc sulphate, as in roasted ore, the leaching of such ore with water will result in the conversion of cadmium to the sulphate and its dissolution in water. In practice, zinc sulphide ore would be roasted and leached with water at or near the boiling point. The small amount of zinc sulphate left in the roasted ore would suffice to convert the cadmium into sulphate which would then be dissolved in the leaching water. Preferably the roasted ore would be introduced into the leaching solution rather than the reverse. (1,129,904, March 2, 1915.)

Tungsten

A process for producing tungsten powder is patented by Robert Rafn, of Porsgrund, Norway, and assigned to the General Electric Co. The production of amorphous tungsten powder by reduction of tungsten trioxide is usually difficult of accomplishment, as a crystalline product most often results. The inventor has shown, however, that by making the reduction in two stages, first with ammonia gas at red heat, producing the so-called blue tungsten oxide, and then with hydrogen at cherry-red heat, the resulting product is a tungsten powder of remarkable fineness. (1,130,197, March 2, 1915.)

Metallurgical Apparatus

Mixing-Drum for Ore-Flotation.—In Fig. 4 is shown a cross-sectional view of a drum patented by J. M. Callow, of Salt Lake City, Utah, for mixing and aerating ore pulps for treatment by the flotation process. The apparatus is designed to accomplish its purpose by less violent means than is usually used in the propeller type of mixer. Hitherto it has been customary to agitate and aerate the mixture and form the frothy float in one vessel; but in the present invention it is designed to mix and aerate the pulp in one vessel, namely, the drum under consideration, without forming a froth, and then deliver the mixture to another vessel or cell in which the froth is formed and recovered with the accompanying mineral.

The mixing-drum consists of a shell A, within which is a lining 16 of porous material adapted to permit the passage of air but not pulp and water. This lining is

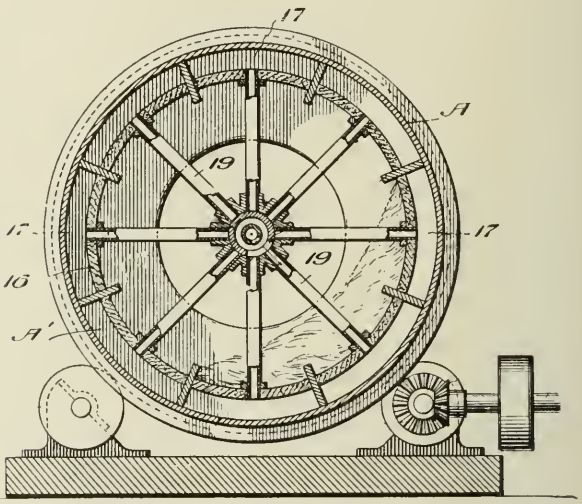


FIG. 4—MIXING-DRUM FOR ORE FLOTATION

spaced apart from the outer casing, forming chambers 17 between the two. The chambers are supplied with a series of pipes 19, for admitting air under pressure; and by means of a suitable valve the air is admitted into successive chambers during the rotation of the drum. Agitation and aeration are thus accomplished as the pulp flows through the drum from feed to discharge end. (1,124,854, Jan. 12, 1915.)

Metallurgical Furnaces

Electric Casting Furnace.—An electric furnace specially adapted to the cast of metals or alloys of high melting point is patented by A. L. J. Queneau, of Philadelphia, Pa. (now in the war with the French army). The furnace consists of a shell of suitable form, containing a crucible in which the melting is done. A combined casting nozzle and electrode extends into the crucible. Both the crucible and nozzle are kept at a high temperature to maintain the metal in a fluid condition and to prevent it from chilling in the nozzle. Means are provided for producing within the crucible a pressure of about 100 lb. per square inch to force the molten metal out through the casting nozzle and into the mold. (1,126,079, Jan. 26, 1915.)

Lining Furnaces by Cement Gun and Torch.—The necessity of keeping furnace walls in good repair, and the obvious difficulty and expense which attend the ordinary methods of doing this work, has led Alfred Schwarz, of New York City, to devise a means of forming and repairing furnace walls in an improved manner. The apparatus required is similar to that used in cement work, the so-called cement gun, in combina-

tion with a high-temperature flame. In operation the ground refractory material to be used for the lining is projected through the gun at velocities ranging from 3000 to 15,000 ft. per minute. As the particles leave the gun they are forced onto the wall and embedded therein in a fused condition, due to the softening effect of the flame. The process may be used while the furnace is hot or cold. As the cement gun and torch are well-known machines, the invention lies in the process of forming or repairing walls of furnaces by projecting comminuted refractory material at a high velocity against the wall and subjecting the wall to a fusing temperature at the time and point of application. (1,125,741, Jan. 19, 1915.)

Another process of forming furnace walls and preventing their disintegration due to heat is patented by JOSEF HEMMER, of Veitsch, Austria-Hungary. Pieces of iron are mixed in the mortar, in which the bricks are laid. (1,123,874, Jan. 5, 1915.)

Chemical Engineering

Fixation of Atmospheric Nitrogen.—A patent by SAMUEL PEACOCK (assigned to the International Agricultural Corporation) relates to a new nitride process of the same general type as the Serpek process. The inventor starts with feldspar which is finely ground and mixed with carbon. He uses for every pound of alumina 0.75 lb. of carbon, for each pound of potash (K_2O) 0.3 lb. of carbon; and for each pound of silica 0.8 lb. of carbon. This mixture is heated in an electric furnace, and as the temperature rises to say 2500 deg. C., a flow of nitrogen gas is maintained through or over the mixture. There is stated to result the formation of a higher carbide of aluminium Al_2C_3 and of potassium carbide K_2C, and this is said to be followed by the formation of carbonitrides of aluminium and potassium, respectively; the following equations being given $Al_2C_3 + 3N_2 = Al_2N_2C_3N_4$ and $3K_2C + 3N_2 = K_6N_2C_3N_4$. Both of these carbo-nitrides are volatile at high temperatures employed, and may be conveniently sucked out of the furnace and collected in bag separators or forced into a digestor. In the digestor the carbo-nitrides are subjected "to the action of superheated steam at a pressure of say 5 to 7 atmospheres, whereupon the following reactions take place, producing alumina, potassium carbonate and ammonia: $Al_2N_2.C_3N_4 + 9H_2O = Al_2O_3 + 3CO_2 + 6NH_3$ $K_6N_2.C_3N_4 + 9H_2O = 3K_2CO_3 + 6NH_3$. Of course, more or less silicon carbo-nitride $SiN_4.C_6N_4$ will also form, but at the high temperature of the furnace charge, it will practically all dissociate and remain in the form of a carbide. By now cutting off the nitrogen and raising the temperature of the furnace to say 2800 deg. C., the well-known product siloxicon, Si_2C_2O, may be obtained, as well as other oxycarbides; and by still further increasing the temperature up to say 3500 deg. C., the lower silicon carbide SiC may be obtained. It will thus be seen that my invention takes advantage of the high temperature necessary to make siloxicon, or silicon carbide, to produce carbo-nitride, without an extra cost of energy, and that from these carbides alumina, potassium carbonate, and ammonia may be produced. Further, the alumina and potash are separated from the mineral and the nitrogen fixation occurs before the temperatures necessary for the formation of the silicon compounds are reached; so that when said last mentioned compounds are to be formed the proper proportions of silica are present in the charge. It therefore follows that the above by-products are obtained, without interfering with the regular process of making the said silicon compounds." (1,129,506, Feb. 23, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

The Consulting Metallurgist and Metallurgical Investigations is the title of a forceful and timely article by Mr. W. B. BLYTH, published in the *Proceedings* of the Australasian Institute of Mining Engineers, No. 16, 1914. The article relates to the work of the consulting metallurgist in the cyanidation of gold and silver ores, and gives many pertinent suggestions regarding the testing of ores, designing and operation of plants, and investigation of existing plants. In addition to technical data, the article contains much wholesome advice. A few of the important matters are here briefly reported.

The author points out the difficulty of interpreting probable commercial results from small scale tests, but adds that "common sense, resource and dependable apparatus are the most valuable assets in comparing work of this nature."

Attention is called to the necessity for co-operation between the mining, the mechanical and the metallurgical engineer, in order to get the best economic results and to safeguard the investigator in matters on which he is not expert. In order to avoid future misunderstanding with the directors of a company it is well to limit the anticipated extraction to a given tonnage, so that future overloading of the plant, with its attendant lowering of extraction, cannot be made to reflect on the investigator.

In testing for the treatment of raw sulphide ores and concentrates dry crushing will give faulty results for the following reasons:

(*a*) That dry crushing and screening is positive crushing, and the softer particles of high specific gravity are not necessarily crushed finer than the hard particles of low specific gravity. Consequently, although screen tests may show that the whole product is fine enough, yet in reality the gangue particles are probably too fine and the sulphide not nearly fine enough. The percentage of colloids in a sample crushed wet to pass a 150-mesh screen is enormously in excess of that in the same sample crushed dry.

(*b*) An excess of abraded iron is produced in dry crushing, and the heat generated expedites oxidation in sulphides that are liable to rapid oxidation—both disastrous factors, under certain conditions, to subsequent cyanide treatment.

It is pointed out that abraded iron is innocuous if the solution is kept alkaline with CaO and no heat be generated. Once oxidized, however, the iron precipitates ferrous hydroxide with lime, and ferrocyanide is formed. The resulting conditions are such that good results are impossible. Ferrocyanide in itself is harmless, but its presence suggests that poor conditions have existed or do exist. Graphite is without effect except that it acts like oil in the flotation process and surrounds mineral with a scum which prevents extraction. The effect of pyrrhotite is not clearly understood. In some cases it acts as a precipitant.

Much stress is laid on the preparation of the sample on which tests and assays are made. The metallurgical engineer is urged to know for himself the nature of underground conditions, the quality and quantity of ore, and the collection of the samples. "Expecting sharp criticism from mining engineers, perhaps few are competent to select, unaided, a representative sample from a mine for the purpose desired."

The investigation of the hardness of the ore is necessary in order to determine grinding conditions. The author's method of computing regrinding factors was outlined in this journal, August, 1914, page 537.

Discrepancies between laboratory and plant roasting are discussed at length. Time is believed by the author to be the most notable factor in these discrepancies. In a comparative test he found that whereas ore remained in a furnace for several hours, attaining its temperature gradually, a muffle roast in the laboratory is complete in

45 minutes. His apparatus and method for getting comparative results are as follows:

"A cast-iron dish 4 in. deep, divided into two compartments, is made to closely fit into an ordinary wind assay furnace fired with coke. The fire is started and the shaft filled with cold coke, well rammed. The cast-iron dish is then placed in position on top of the fire and the edges packed tight with small coke. A charge of the ore to be tested is placed in one compartment (1000 grm.), while a charge of an ore on which dry-crushing and cyaniding results are already proved is placed in the other. The draught is kept well back, and the heat gradually raised with constant rabbling. In about 30 min. sulphur should commence to come off, and this should all be off in two hours. After two hours the heat can be raised as much as possible, and finally the lid of the furnace is closed for about 10 min. Rabbling must be carried on carefully all the time, as any fritting precludes success. If subsequent cyaniding experiments on the ore (on which the process is proved) give plant results, then the results obtained on the new ore may be accepted as reliable. By this means the writer has obtained reliable results which have been borne out in the plant."

Amalgamation tests on a small scale cannot be relied upon, and inasmuch as amalgamation plays such a relatively unimportant part in cyanidation nowadays, the author prefers merely to amalgamate in a pan for the removal of coarse gold and not to indicate what saving can be made by that process.

Leaching tests usually give dependable results. They should be made in a high column, say, 6 ft., and aeration of the sand and solutions should be attempted.

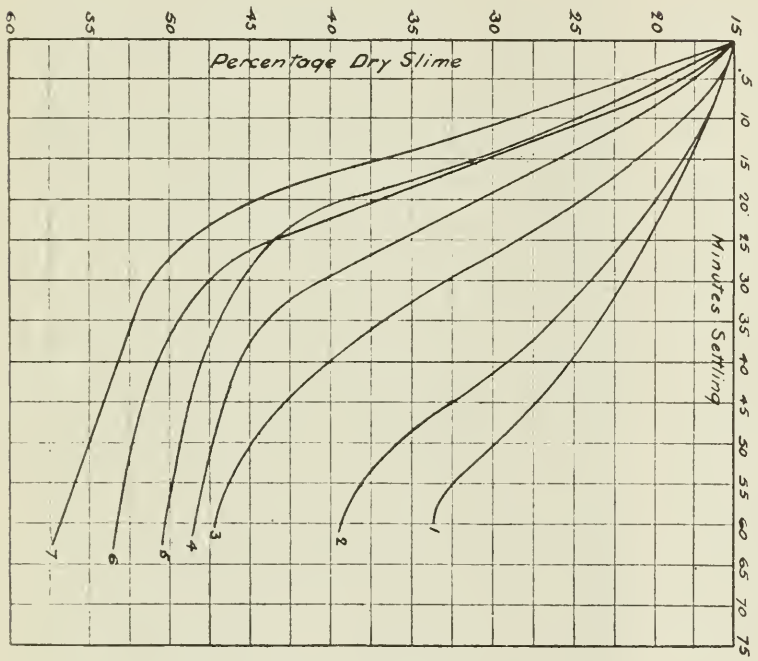


FIG. 1—SLIME SETTLEMENT CHART

The determination of the slime-settling rate is an important matter. The author has elaborated a standard slime-settlement chart, shown in Fig. 1, based on tests conducted as follows:

Two 1000 cc measuring flasks were obtained of similar height (15 in.). A 15 per cent pulp of the slime to be tested was introduced into the flask. The pulping medium tested 0.05 per cent KCy and 0.013 per cent CaO; 15 per cent was determined on as representing a fair plant thickness. The test was conducted on the sampled slime from a number of different mines which had efficient settlement plant already installed. The settlement test was conducted in each case under identical conditions with regard to the determining factors, but the particular mine water was used in each case. There are mine waters varying from 0.1 per cent to 26 per cent of solids in Western Australia, and this is a factor of great importance in making settlement tests. Settlement was allowed for one hour in each case, and two tests were conducted—one in the alkaline cyanide solution already described, and the other in the ordinary non-alkaline mine water. The diagram (Fig. 1) shows the tests conducted in the alkaline solution only. The diagram is of considerable value in designing plants, as, knowing the settlement area for a given tonnage of slime on the mines illustrated on the diagram, it is only necessary to compare a settlement test conducted under similar conditions to arrive at the settlement area required to do definite work on the ore under examination."

Referring to new processes designed to supplant proved methods, the author wisely observes: "Let the old-established producing mine do the experimental work. The new producer has too much at stake to take any chances."

In making vacuum-filter capacity tests care must be taken to filter the product in exactly the same condition experimentally as it will be obtained in the plant. The question of replacement of pregnant solution with wash solutions is a criterion of the work. A good way to conduct these tests is to take a series of solution samples from the vacuum pump discharge every five minutes during the wash. When the assays are arranged in graphic form they show the replacement of gold solution by barren wash, and when two washes are used the replacement of barren solution by water is indicated.

Special attention is directed to the assay of slime residue and the probability that such assays will be faulty unless the greatest care is exercised. The losses which may occur in drying the sample, especially the losses of dissolved gold in the residue, are remarkable. This point was touched on at some length in this journal, February, 1915, page 119. The use of precipitants is advisable before drying and assaying. Cuprous chloride or Whitby's mixture (copper sulphate, sodium sulphite and sulphuric acid) are suitable precipitants.

In estimating working costs after having determined the economic solution of the extraction problem, the metallurgist should lay out the flow sheet in detail and estimate treatment costs. The type of plant required must be determined by sketching out in detail all the possible economic alterations. Then detailed treatment costs should be prepared, and a balance sheet made showing the net result of each alternative scheme. "Cost estimates can only be safely entrusted to experienced and conservative operators." Fixed and variable costs must be considered, especially the latter, as they vary with each individual ore.

Determination of Gold and Silver in Cyanide Solutions.—In the *Bulletin* of the American Institute of Mining Engineers for February, 1914, Mr. L. W. Bahney, of New Haven, Conn., presents a method for determining gold and silver in cyanide solutions, of which we present an abstract. Five assay tons of solution (146 cc.) is placed in a 250-cc. beaker. Add successively 20 cc. of a 20 per cent solution of lead acetate and 15 cc. concentrated hydrochloric acid. Then place a ¼-in. rod of zinc in the beaker and boil the solution for five minutes. Fill with cold water; then decant about half, and again fill with cold water. Withdraw the zinc rod, freeing it from particles of lead sponge. Wash the sponge several times with water, press sponge together to remove water, decant and wash again. Place the sponge in a piece of sheet lead 2 in. square, fold and cupel. In case the sponge does not cohere in a single piece it may be filtered on a piece of lead foil formed into a cone and containing some test lead.

Copper

Oil-Fired Reverberatory Smelting at Nevada Consolidated Copper Co.—In a paper presented at the February meeting of the American Institute of Mining Engineers Mr. R. E. H. Pomeroy gave some data on reverberatory copper smelting at McGill, Nevada. The furnace is 132 ft. long with an average width of 18 ft. 10 in. at the skim-line level. It is equipped with two 400-B.hp Stirling waste-heat boilers. The fuel is California crude petroleum of 16.5 deg. B. sp. gr., and with a flash point of 199 deg. Fahr. It is heated to 200

TABLE I.—ANALYSES

Material	Per cent Cu	Per cent SiO_2	Per cent Fe	Per cent CaO	Per cent Al_2O_3	Per cent S
Concentrates roasted	6.48	28.4	27.0	...	5.2	28.4
Cold secondaries ...	9.37	19.9	43.4	...	3.4	8.4
Hot converter slag..	2.01	27.2	46.2	...	4.5	1.2
Fettling slimes	3.32	65.8	7.3	...	8.3	7.6
Lime rock	....	2.1	0.8	51.1	0.8	...
Roaster flue dust....	5.85	40.4	15.2	0.7	6.6	9.2
Reverberatory matte.	27.46	0.4	40.8	...	0.5	27.2
Reverberatory slag.	0.298	42.2	28.4	9.5	6.8	0.4

TABLE II.—SCREEN ANALYSIS OF CONCENTRATES ROASTED

Mesh	+30	+40	+60	+80	+100	+150	+200	200	Average
Weight, per cent.	9.7	7.1	13.4	10.1	11.9	13.5	9.6	24.1	...
Copper, per cent.	3.23	4.33	6.16	7.11	7.28	7.60	7.27	6.88	6.48

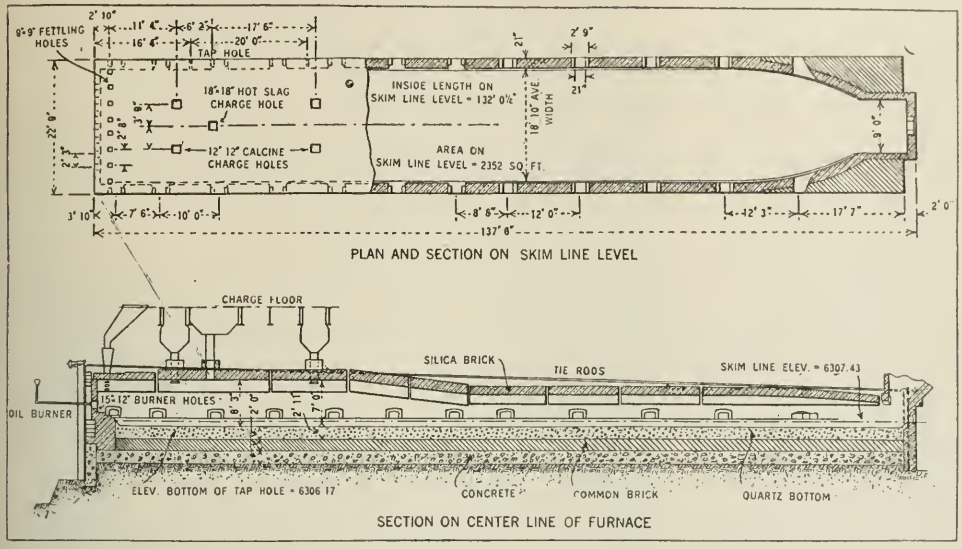

9-9" FETTLING HOLES
TAP HOLE
18"×18" HOT SLAG CHARGE HOLE
12" 12" CALCINE CHARGE HOLES
INSIDE LENGTH ON SKIM LINE LEVEL = 132' 0½"
AREA ON SKIM LINE LEVEL = 2352 SQ. FT.
PLAN AND SECTION ON SKIM LINE LEVEL
CHARGE FLOOR
SILICA BRICK
TIE ROOS
SKIM LINE ELEV. = 6307.43
15-12" BURNER HOLES
OIL BURNER
ELEV. BOTTOM OF TAP HOLE = 6306.17
CONCRETE
COMMON BRICK
QUARTZ BOTTOM
SECTION ON CENTER LINE OF FURNACE

FIG. 2—REVERBERATORY FURNACE NO. 2 AT MC GILL

nersville blower at 40 oz. Air supplied at the burners amounts to about 10 per cent of that required for complete combustion, the balance entering through the burner openings in the firing wall. Combustion is practically complete, less than 0.5 per cent CO existing in the gases at the front of the furnace. Evaporation at the waste-heat boilers was 4.81 lb. water per pound of oil burned.

Plan and section of the furnace are shown in Fig. 2, and in Fig. 3 is given a graphical representation of the side-door temperatures at different intervals after charging. Tables I to IV inclusive give interesting data.

The vital points in reverberatory furnace smelting at McGill are summarized on top of page 254.

TABLE III.—PERFORMANCE OF FURNACE

Month, 1914	Furnace Days	Total Charge per Furnace Day—Tons	Daily Tons per 100 Sq. Ft. Hearth Area Total Charge	Solid Charge per Furnace Day—Tons	Daily Tons per 100 Sq. Ft. Hearth Area Solid Charge	Oil Fired per Furnace Day—Barrels	Gross Oil Ratio Bbl. per Ton: Total Charge	Gross Oil Ratio Bbl. per Ton: Solid Charge	14-lb. Basis Waste-Heat Recovery, Per Cent	Net Oil Ratio Bbl. per Ton: Total Charge	Net Oil Ratio Bbl. per Ton: Solid Charge
April	30.0	694	29.53	609	25.91	371	0.53	0.61	32.48	0.358	0.412
May	30.8	665	28.29	581	24.72	384	0.58	0.66	34.99	0.377	0.429
June	30.0	659	28.03	582	24.76	372	0.56	0.64	36.43	0.356	0.407
July	31.0	721	30.68	628	26.72	415	0.58	0.66	33.51	0.386	0.439
Average ...	30.4	685	29.15	600	25.53	385	0.562	0.642	34.35	0.370	0.421

NOTE.—The above period does not cover a complete campaign.

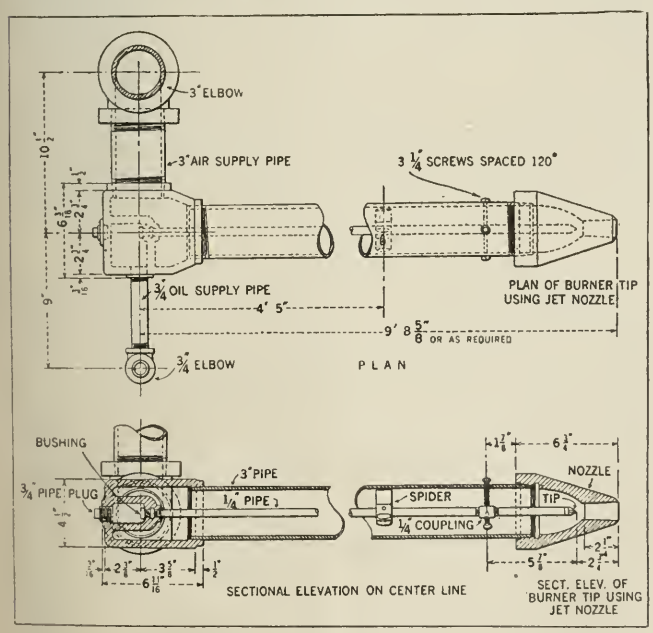


FIG. 3—LOW-PRESSURE OIL BURNERS, STEPTOE TYPE

deg. Fahr. before going to the burners. Feed is by gravity (34 lb. static pressure) to low-pressure blast burners shown in Fig. 3. Blast is supplied from a Con-

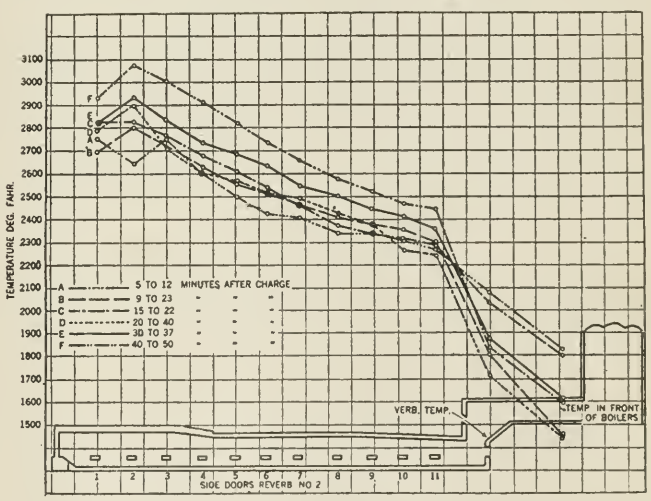

TEMPERATURE DEG. FAHR.
A 5 TO 12 MINUTES AFTER CHARGE
B 9 TO 23
C 15 TO 22
D 20 TO 40
E 30 TO 37
F 40 TO 50
VERB. TEMP.
TEMP IN FRONT OF BOILERS
SIDE DOORS REVERB NO 2

FIG. 4—CURVES SHOWING SIDE-DOOR TEMPERATURES OF REVERBERATORY NO. 2 TAKEN AT DIFFERENT INTERVALS AFTER CHARGING

TABLE IV.—PERCENTAGE ANALYSIS OF CHARGE SMELTED

Month, 1914	Calcines	Cold Secondaries	Hot Converter Slag	Fettling	Lime Rock	Roaster Flue Dust
April	59.3	8.0	12.2	4.6	12.9	3.0
May	58.7	8.0	12.6	4.8	12.3	3.6
June	63.4	6.6	11.7	5.4	12.1	0.8
July	58.4	7.7	12.9	5.3	13.0	2.7
Average..	59.9	7.6	12.4	4.9	12.7	2.5

Factors affecting efficient combustion of the fuel:
1. The use of a burner to give a proper atomization of the oil so as to obtain a long uniform flame without overheating any portion of the furnace.
2. Regulation of the draft so as to furnish the proper mixture of gases for complete combustion in the furnace.
Factors affecting the operation of the furnace proper:
1. Careful preparation of the charge by adequate mixing of all ingredients before charging.
2. Addition of enough lime rock, preferably coarse, to produce an active boiling in the furnace.
3. Maintaining a deep bath of molten matte to equalize and distribute the heat over the whole of the hearth.
4. Frequent skimming so as to carry only a thin layer of slag over the matte bath.
5. Operating the furnace for the best smelting conditions, ignoring the waste-heat boilers as factors in the power supply.
Factors affecting the life of the furnace:
1. The furnace roof set high over the hottest portion of the hearth.
2. Frequent fettling to protect the side walls.
3. Frequent charging and active charge mixtures to avoid floater and blanket formation requiring excessive firing.

Metallurgical and Chemical Engineering in Great Britain

(By our London correspondent)

Birmingham Section, Institute of Metals

Mr. T. J. Baker, Sr.'s paper on "Bronzing Processes Suitable for Brass and Copper" was read on Jan. 26, and dealt with steel-bronzing, with possibilities of variation in coloring on the same object, by stopping out, or employing an intermediate coppering bath for the brass: also the production of black, deep blue and antique effects. The variety of colors which can be obtained on brass-work, such as gold, crimson, purple, blue and lavender, though not employed commercially, suggest a field worthy of investigation by the producers of jewelery.

Refractory Materials and the War

In a contribution to the *Journal* of the Royal Society of Arts, Mr. Alfred B. Searle points out that the importation of bricks for building coke ovens and other furnaces from Belgium has ceased, and that consequently efforts are being made in this country to bring firebricks up to the specification required by the continental builders.

Similarly retorts for the manufacture of coal gas are not now obtained from Germany. The relative values here appear to be more indeterminate, as some German engineers imported British retorts, and vice versa.

Iron and Steel Institute Dinner

The annual meeting of the Iron and Steel Institute will be held by kind permission at the Institution of Civil Engineers on Thursday and Friday, May 13 and 14, 1915. The date for the annual dinner has been provisionally given as May 13 but this will be the subject of a future announcement.

Scottish Oil Trade

A Scotch company have erected a plant at Addrewell for operation of a German patent process, the rights of which were acquired last spring for the conversion of oil products into commercial materials.

Institute of Industry and Commerce

The interests of chemical manufacturers in this country are receiving the attention of a central committee which meets early in February at the offices of the Institute of Industry and Commerce, Strand. A preliminary meeting has already been held.

Platinum in Russia

The British vice-consul at Ekatermburg gives some interesting notes on the platinum position. The present situation has, apparently, resulted in an interruption to the regular export trade, due to continental buyers not taking up contracts, and there should therefore be temporarily more platinum on the market than usual.

Heating of Mines

The heat in deep mines was treated of by Professor Cadinaw, D.Sc., in his lecture at Ashby-de-la-Zouch on Jan. 23. He took the sources of heat under three heads: (1) Heat due to rock temperature; (2) heat due to compression of the air, and (3) heat due to oxidation. Heat could not be modified by the introduction of moisture in deep mines, as this was detrimental to workmen, and it was also imperative in deep work to keep the air dry. For the prevention of oxidation the following means appeared the most effective: (1) Lining the roadways with non-oxidizable material; (2) measures for preventing the spreading of coal dust, and (3) complete re-filling of spaces left after extraction of coal. The lecturer was very optimistic as to the prevention of explosions in connection with coal dust.

Coal Prices

The present high level of coal prices in this country is attributable to a variety of causes working together: limited production, due in some measure to absence of men at the war, and also to the high remuneration permitting of very short hours being worked by the miners being among the chief. So far as the southern centers of population are concerned, especially London, the transport element comes certainly into consideration, and certainly has its influence on the price. The ultimate tendency of the kind of squeeze which the major portion of the community are experiencing, must be in the direction of nationalization of the more important national assets to such an extent as to avoid leaving the country entirely to the direction of a limited number of owners or an organized privileged class of operators.

Peat Fuel

The high price of coal has turned the general attention to other fuels. The possibility of utilizing peat in a water-gas process was originally suggested by Dr. L. Mond, and two plants acting on this principal are actually working in Italy, at Orentano and Codigoro. As described by Prof. Ugo Rossi, these consist of a turret-shaped oven into which the dried and broken peat is thrown. Steam and hot air are admitted by means of jets, and the water in contact with the incandescent mass produces Mond gas, which collects at the top of the oven.

The gas is then subjected to two purifying processes, and is ultimately used for power purposes. The purifying process involves the production of sulphate of ammonia, a peat containing 2.5 per cent of nitrogen yielding about 1½ cwt. of sulphate of ammonia to the ton.

Oil

If the civilization of the future is to follow the oil deposits in the same way as that of the present has adhered (with the usual marked exception) to the coal fields, there is still considerable prospect of improved circumstances for the world's population. While recent additions to the oil areas in Russia can hardly be said to have proved their value so far, the proximity of Roumania and Galicia may be looked to to remedy any existing deficiency. Turkey contains promising districts for investigation, which would be worthy of the attention they will probably ultimately attract. In Africa, Algeria and Egypt have both been the subject of recent exploration in this direction, and a number of wells were completed in the latter. Taking, in fact, the Eastern map of Europe, as well as the adjacent portions of the map of Africa, it appears that civilization, when not already established on the oil country, is satisfactorily progressing toward it.

Copper Cyanide Plating Solutions*

BY DR. MAX C. WEBER

I have chosen as a subject the working of a copper bath, as this is by far the most extensively used and also the most instructive solution.

There are three things which are necessary for the deposition of metal—current, electrode and electrolyte. As the electrolyte or plating solution is the most important, I will confine myself to this item.

The object of employing cyanide solutions for the deposition of copper is to be sought in the fact that in such solutions iron does not replace copper, notwithstanding their places in the electrolytic series, a phenomenon which is due to the complexity of the salt in which the copper is present. The complex salt, which makes this feasible, is the double cyanide or sodium copper cyanide, the anion of which is Na, the cation $CuCy_2$; that is, by the action of the electric current, Na travels toward the cathode, $CuCy_2$ toward the anode. In other words, copper is not present in an ionized stage. Under proper current conditions, *i. e.*, not too high current density and a suitable concentration of the solution, Na is not discharged at the cathode, but reacts with an undissociated part of $NaCuCy_2$, as per the following equation:

$$Na + Na\ CuCy_2 = Cu + 2\ NaCy,$$

thus showing that the deposition of copper is a secondary reaction, and that free cyanide is formed. On the anode, the anion $CuCy_2$ combines with the copper of the electrode, forming cuprous cyanide $CuCy_2 + Cu = 2\ CuCy$.

Cuprous cyanide is insoluble in water, but soluble in cyanide solution, and for this purpose the free cyanide generated at the cathode is required. Supposing we have proper conditions—low current density on both electrodes—enough free cyanide is produced on the cathode in order to keep in solution the cuprous cyanide formed on the anode. As the free cyanide of the cathode is really needed on the anode for dissolving purposes, and as in a still solution the mixing velocity is very slow, stirring and warming of the electrolytic bath would expedite this matter considerably and bring the bath very near to an ideal stage. However, warm and agitated solutions require a more careful observation on account of which these two items have not as yet been paid the attention they actually deserve.

If too high a current density is used on the cathode, not all the Na ions act reducing on the sodium copper cyanide, but are partly discharged, forming sodium hydrate and hydrogen in connection with the water of the bath:

$$Na + H_2O = NaOH + H$$

This reaction accounts for the development of hydrogen or gasing at the cathode. It means that less copper is deposited per ampere hour and not sufficient free cyanide formed in order to keep the anode clean. Therefore, the solution necessitates the addition of sodium cyanide, otherwise the anode becomes coated and the passage of the current is interrupted. Too high a current density on the anode leads to the same result; covering of the electrode with an insulating film of cupri-cupro cyanide.

In regard to current density, it must be borne in mind that warmed and agitated solutions can be worked with a higher current density than cold ones, and that a density of approximately 30 amperes per square foot is quite feasible without yielding a burned and blistered deposit.

Another feature which is quite interesting is the amount of metal deposited per ampere hour. In a copper cyanide solution which contains the metal in the cuprous state, the same number of ampere hours should yield twice as much metal as in an acid bath, providing, of course, all the favorable conditions are prevailing, *i.e.*, a strong solution, warmed and agitated, worked with a minimum amount of free cyanide at a low current density. As, however, common plating solutions are worked on nearly the contrary conditions, the relative amount obtained from a cyanide bath is much lower. How much lower depends entirely on the relative conditions, and only one feature should be emphasized, which has been mentioned above: that the more hydrogen develops on the cathode, so much lower is the percentage of the metal deposited per ampere hour. A low current density results in a high weight of the metal deposited per ampere hour, while the deposition is slow. A high current density yields a lower weight proportionately per ampere hour, but consuming less time for a certain weight of metal deposited, resulting in a greater deposition of metal per hour.

Furthermore, cyanide solutions yield a finer, more homogeneous texture and brighter metal film than the acid baths on account of the secondary copper deposition and because hydrogen may develop more freely on the cathode in such a solution without fear of burning or blistering the deposit.

These few remarks give an idea how complicated the reactions in a plating solution are, and that it requires skill and experience to procure a satisfactory deposit.

The first part of this paper has shown that the constituent which is essential in a copper cyanide bath is the double salt, sodium copper cyanide, consisting of copper cyanide and sodium cyanide, which is easily formed by adding the necessary amounts of each chemical to water. A high-grade sodium cyanide has been obtainable for quite a number of years, but copper cyanide could only be procured at prices which made its use prohibitive for technical purposes.

For this reason many salts—one might call them subterfuges—have been used which were intended to substitute copper cyanide and form the same when brought together with cyanide solution. One should bear in mind that whatever copper salt is brought together with cyanide solution, the final compound is the double salt, sodium copper cyanide. Another fact which should not be lost sight of is that one chemical can replace another only to the extent of the requisite elements, and that by the reaction of two such salts, always a by-product is formed which contaminates the compound desired.

This is the case with the copper cyanide. Copper carbonate, copper sulphate, copper acetate, cupri-cupro sulphite have been employed in order to form copper cyanide in connection with sodium cyanide and water. That by these reactions an inert by-product consisting of sodium sulphate or sodium sulphite or sodium acetate or sodium carbonate is formed to a high percentage every one was aware of, but took it for granted as the product necessary, *i.e.*, copper cyanide was not obtainable commercially.

When using copper carbonate, which is really basic copper sulphate containing a small percentage of carbonate, according to the temperature at which it is precipitated, approximately one-half pound of inert matter is formed for every pound of copper carbonate, being composed of sulphates and carbonates. By the use of copper acetate, or cupri-cupro sulphite this inert matter is still further increased, and for each pound of the compounds used, from nine to ten ounces inert salts are produced. These salts accumulate in the bath more and more with every addition of the respective copper salt, and finally yield such a dense solution, which being overloaded with these waste compounds cannot be worked

*A paper presented before the Lewis Institute, Chicago, Ill.

in a satisfactory manner any longer, the plated articles being blistered and the solutions are of necessity discarded.

The reason for this is that a bath of this kind has a relatively low metal concentration and a much higher one of the inert salts. As a rule, the electric current deposits the metal easiest to discharge, which in this case is the alkali metal. Therefore, as the current density increases an excess of hydrogen is generated, which causes burning, and the current output drops considerably.

After considering this crude method of forming copper cyanide one should remember that the copper in a cyanide plating solution is in the cupro stage, while copper carbonate, copper sulphate, copper acetate are cupri salts, and cupri-cupro sulphite is a mixture of both. This means these salts must be first reduced to the cupro state before they are fit for plating. This reduction is executed at the cost of the sodium cyanide which is actually intended for bringing the copper metal into solution only. Further, neutral copper salts as copper acetate, copper sulphate and cupri sulphite, when brought in contact with cyanide solutions, form cupri cyanide first, which, being an unstable compound, decomposes into cupro cyanide and cyanogen, which latter escapes into the air, and on account of its highly poisonous character is most detrimental to the health of the plater.

Taking into consideration all the disadvantages resulting from the present method for producing a plating solution, every progressive plater should greet with joy the fact that a chemically pure cupro cyanide is now on the market at a price making its use more economical than that of any other copper salt which has been accomplished by new manufacturing methods worked out by the author of this article.

Cupro cyanide contains nothing but the ingredients necessary in a plating solution—copper and cyanogen—so that by dissolving it in cyanide solution no inert, unnecessary products are added. This enables the plater to have perfect control of his solutions at all times, as whenever metal is needed he adds it in the form of copper cyanide, and, when cyanide is needed, sodium cyanide, thus simplifying matters. On account of its high percentage of metal—it contains 70 per cent pure copper, the rest being cyanogen—solutions highly concentrated in metal can be worked at a relatively low specific gravity. This is a further advantage, as a bath low in density is much more easily controlled than a very concentrated one.

Copper cyanide being a cupro salt, does not consume any cyanide in order to be transferred to the cupro stage, and because of its being a cyanide itself it requires less sodium cyanide than any other copper salt to yield the double salt sodium copper cyanide, the essential constituent of a plating solution. This fact points out a more economical method for producing a plating solution. In other words, it saves money. When one buys a metal salt for plating one should not forget that it is not the price of the metal in the salt itself which constitutes the economy of the salt, but the price at which the metal is put into solution as a double cyanide. It is this economy of the copper cyanide combined with its high technical qualities which makes copper cyanide superior to any other plating salt.

The figures in Table I give a comparison of plating solutions produced with different copper salts and are the results of actual tests. The metal contents of the solutions are the same in Table I.

After continuous operations for two hours it was found that while the solution made up with copper cyanide remained almost constant—that is, the relative proportions of metal and cyanide were practically the same—the solution made up with the other salts became unbalanced. The anodes coating over requiring further additions of cyanide, showing once more that solutions made up with chemically pure copper cyanide gave maximum efficiency.

Table I

Copper cyanide, 70 per cent copper:		
100 lbs. copper cyanide at 42c. per lb.	$42.00	
100 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	22.00	$64.00
Copper carbonate, 50 per cent copper:		
140 lbs. copper carbonate at 14c. per lb.	$19.60	
239 lbs. sodium cyanide, 129 per cent, at 22c. per lb	52.58	$72.18
Cupri-Cupro sulphite, termed red copper compound—40 per cent copper:		
175 lbs. red copper compound at 30c. per lb.	$52.50	
160 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	35.20	$87.70
Copper acetate, 31 per cent copper:		
220 lbs. copper acetate at 25c. per lb.	$44.00	
193 lbs. sodium cyanide, 129 per cent, at 22c. per lb.	42.46	$86.46

As so-called copper carbonate was the most extensively used, I gave this solution special attention and found, after considerable experimenting, that in order to obtain a solution with sufficient free cyanide to obtain a fairly balanced solution the following proportions were necessary:

140 lbs. copper carbonate at 14c. per lb.	$19.60	
280 lbs. sodium cyanide, 129 per cent., at 22c. per lb.	61.60	
		$81.20

These comparative figures vindicate once more one of the most important rules in chemistry—that pure materials not only give the greatest efficiency, but are the most economical.

In the present time, which is distinguished by the endeavor to obtain an end as simply and as economically as possible, where everything is standardized in order to obtain the best results at the lowest cost, no farsighted man can dispute the fact that copper cyanide brings this desired standardization to the plating industry which means utmost economy and high results.

Blowers and Fans.—The Clarage Foundry & Mfg. Co. of Kalamazoo, Mich., has recently published a catalog describing Clarage type C.I., cast-iron volume blowers. These fans are built in four sizes, 5, 6, 7 and 9, and the number in each case is the same as the diameter in inches in the suction or outlet connection. The housing or fan case is cast in one piece, and is supported by cast-iron side plates. These plates are larger than the fan wheel, and by merely taking out eight cap screws and removing the plate the wheel may be withdrawn from the housing. This same feature makes these fans adjustable and reversible, as any one of seven different directions of discharge may be secured, and the arm supporting the bearing may be placed on either side of the fan. Although furnished regularly as single inlet exhaust fans with a collar for the suction pipe or intake side it is possible by removing the collar and plate to use these fans or blowers having two inlets, and thus obtain the resulting high efficiency. The special dust-proof, oil-tight, enclosed bearings are features of importance in dusty installations, and the large supply of oil assures a cool running machine. To invert the fans the only change necessary is to interchange the positions of the oil supply pipe and the plug in the bearing. The type C.I. fans, as single-inlet exhausters, may be used to remove smoke, chemical vapors, or fumes from forge fires, stoves, ranges, vats or kettles, exhausting air in small ventilating installations for toilet rooms, telephone booths, etc., or they may be used to convey light material, such as removing dust from emery wheels, or tumbling barrels or shavings from wood-working machines. As double inlet blowers the type C.I. fans furnish blast for forge-draft fans for small boiler plants.

Refractories of the Rocky Mountain Region, and Some of Their Products

BY J. C. BAILAR

Before using a new piece of chemical porcelain ware the chemist has long been accustomed to remove a stamp bearing the word "Germany," and coupled with this habit of years has come the fixed belief in the minds of many people that such ware cannot be made in the United States. The same idea once prevailed with regard to fire-clay goods. The first smelters in the Rocky Mountain region used fire-brick made in England; that assayers also imported muffles, crucibles and scorifiers. It is possible that some American ware was used, but where the fire was hottest no brick was used that did not bear the then magic word "Battersea." Fortunately for the mining industry of this region, the first smelters were erected near a deposit of excellent fire-clay. This deposit marks the eastern boundary of the Rocky Mountains in Colorado and has been opened

FIG. 1—HEROLD CHINA AND POTTERY CO., GOLDEN, COLO.

in many places for a distance of approximately 250 miles. It is accompanied by large bodies of shale and plastic clay suitable for building brick, terra cotta, roofing tile, sewer pipe and the cheaper grades of pottery. In the nearby hills are found quartz and feldspar in abundance. There is enough of each of these to supply raw material for ceramic industries for several generations.

Superior Quality of the Fire-Clay

Tests made by the United States Geological Survey and others show the fire-clay to be one of the best known; but fifty years of practical use had already proved that. The chemical characteristics of some of the clays are shown in Table I. Numbers 1, 2, 3 and 4 are Golden fire-clays; No. 5 is a red-burning plastic clay from Golden, and No. 6 represents an average of fifty paving-brick shales. The analyses are from sources of undoubted reliability.

TABLE I

Analyses of Colorado Clays and Shales

Number	1	2	3	4	5	6
SiO_2	50.35	45.99	46.61	56.41	60.60	56.00
Al_2O_3	34.44	36.94	37.20	26.37	18.86	22.50
FeO	0.75	0.75	0.15	0.00	6.70	6.70
MgO	trace	0.36	0.25	0.20	1.50	1.40
CaO	0.00	0.23	0.44	0.29	2.70	1.20
Na_2O	0.10	0.45	1.23	1.55	....	3.70
K_2O	0.48	0.48				
Ignition loss	13.88	14.13	13.65	14.66	9.32	7.00

The fire-brick made from the clay deposits in this region probably were produced in Golden, Colorado, in the early sixties. They were molded by hand and reshaped by means of a hand press. This method has not been entirely abandoned, though machines are now used for the greater part of the work.

Early in its history the brick industry was enlarged to include the manufacture of assayers' supplies. This department of the work has grown until the Colorado-made assay crucible is known not only from Klondyke to Cape Horn, but has crossed the ocean seeking wider fields of usefulness. Certainly the name "Battersea," once so potent in the assayer's mind, has taken its proper place among the historical relics in Colorado. At the present time two companies are engaged in the manufacture of assay goods on a large scale. The Denver Fire Clay Company and the Mine & Smelter Supply Company both have factories in Denver, bringing the clays from the beds at Golden. The excellence of the products arises, of course, not only from the chemical nature of the clay, but from its physical characteristics as well. And added to these natural advantages in the raw material must be credited the long and expensive experimentation that the producers have conducted in order to determine the proper mixtures, methods of handling, tempering, molding and burning. These latter constitute the secrets of the trade, which are closely guarded in the clay-working industries.

Good sewer pipe and pottery also are being made from the Golden clays, several Denver firms being engaged in this line of work.

Fire-Proof Porcelain Ware

It has long been known that fire-proof goods of a finer grade than bricks and crucibles could be made from the Golden clays. In the fall of 1909 Mr. John J. Herold went to Golden to investigate the possibilities of making cooking utensils. While carrying on these investigations, Mr. Herold was compelled to make ornamental ware to pay expenses, and for nearly a year he was the only workman in his plant. Finally, however, he succeeded in interesting local capital and the Herold China & Pottery Company was organized, with Mr. Adolph Coors, president, and Mr. Adolph Coors, Jr., manager. The factory was greatly enlarged, as shown in Fig. 1, and an additional kiln has been built since the picture was taken. At present fifty people are employed.

About the time the company was organized a few casseroles and evaporating dishes were made and put to practical use in chemical laboratories with fairly good results. Later, when time could be spared from the regular work of the plant, several small lots were made and tested. Each lot was of a different mixture, and consequently there was no uniformity, each was a separate experiment. Every piece made showed excellent resistance to acids and alkalies, and some of the mixtures withstood alternate heating and cooling remarkably well. In fact some lots were superior to the best imported ware, when the two were used in the laboratory side by side.

Chemical Laboratory Ware

Until recently no chemical ware was made except these experimental lots, as the company devoted all its energies to the manufacture of cooking utensils. Now, however, the line of chemical ware is well established, and includes evaporating dishes, casseroles, porcelain crucibles, spatulas, mortars, glazed and unglazed tubes, and in fact everything that the chemist may require. Some battery cells made for the refinery of the United States mint in Denver last 50 per cent longer than the Royal Berlin cells that had been previously used. These products of the Herold factory have been duly investigated by chemical supply houses which have offered to contract for the entire output. It is understood, however, that the manufacturers prefer not to make such a contract, but sell in the open market. This factory has demonstrated beyond question to the writer that we can produce our own chemical porcelain ware in this country, and it does not require an optimist to predict that, with reasonable economic conditions, the stamp "Made

in Germany," so common on chemical porcelain, will gradually disappear.

Enameled Brick

These notes on the manufacture of refractories in the Rocky Mountain region would not be complete without mention of the product of the Sanitary Brick Company, of Golden. This company makes a high-grade enameled brick for both interior and exterior work. The process of manufacture is very different from the one generally used. The bricks are made by the stiff-mud process, and by an ingenious device the enamel is put on by the same machine. When somewhat dry, the enameled face is dipped into the glaze, and when the drying is complete the bricks are burned not in saggers or muffle kilns, but in common down-draft kilns such as are used in the manufacture of building brick. The enamel is about ⅛ in. thick and is united to the body just as the glaze is united to a dinner plate. No line of cleavage can be found between the body and enamel when the brick is broken. It is scarcely necessary to say that to make and enamel ware in one operation, glaze the ware while green and complete it in one burn is not the usual procedure. These bricks will be used for part of the interior finish of the new Union Depot and Post Office now being built in Denver.

Golden, Colo.

Regulation of Electrotyping Solutions

The Bureau of Standards has started an investigation of electrotyping problems and the first result is Circular No. 52, just issued and entitled "Regulation of Electrotyping Solutions." The Bureau is not yet able to make definite recommendations regarding the best composition of solutions to be employed for any given method of operation for either copper or nickel electrotyping.

The circular first discusses the expression of the density of a solution either in degrees Beaume or by its specific gravity and gives two conversion tables. As to the composition of solutions it is said that in view of the almost universal use of the metric system in chemical analysis and other scientific work, preference will be given to the metric system in expressing the composition of the solutions. Since, however, the ordinary United States units are generally employed in electrotyping and similar commercial work, the values will also be expressed in such units. In making such calculations the following values and equivalents will be employed:

One avoirdupois pound = 454 grams.
One avoirdupois ounce = 28.35 grams.
One United States liquid gallon = 231 cu. in.
One United States liquid gallon = 3.785 liters.
One liter = 1000 cc.
One liter of water weighs 1000 grams.

From these values the following simple rules may be derived:

(*a*) To determine the approximate capacity of the vats in gallons, divide the cubical contents in cubic inches (up to the height of the solution) by 231.

(*b*) To convert grams per liter (g/l) to ounces per gallon (oz./gal.), multiply by 0.134; or divide by 7.5. Thus 50 g/l is equal to $50 \times 0.134 = 6.7$ oz./gal.

(*c*) To convert grams per liter to percentage by weight divide the grams per liter by ten times the specific gravity of the solution. Thus for a solution with a specific gravity of 1.15, 50 g/l is equal to

$$\frac{50}{10 \times 1.15} = \frac{50}{11.5} = 4.3 \text{ per cent.}$$

The portion of the circular which deals with regulation of the copper solution we give in full as follows.

Copper Solutions

1—GENERAL INFORMATION

The solutions usually employed for copper electrotyping contain, in addition to water, only copper sulphate and sulphuric acid. Since these substances and also the anode copper are usually fairly pure, there is no marked tendency for impurities to accumulate in the solution. The principal changes taking place in the composition of such solutions are due to two causes, (1) mechanical loss of the solution adhering to the "cases" (cathodes) when removed from the vats, and (2) solution of a greater amount of copper from the anodes than is deposited on the cathodes. The first factor would in itself

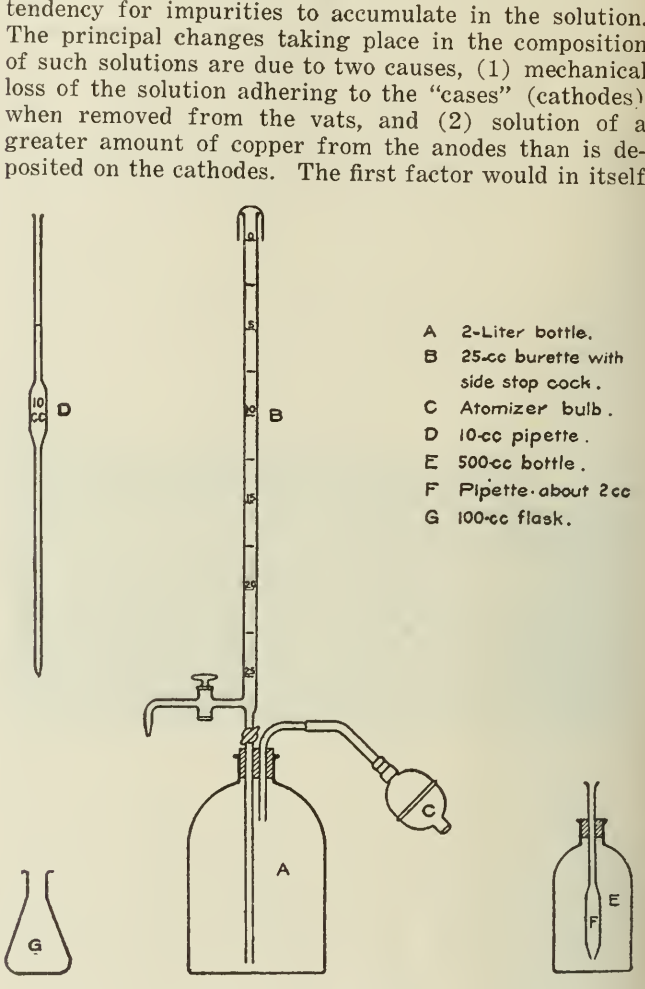


FIG. 1—APPARATUS FOR TESTING ACIDITY

cause a decrease in the density of the solutions, if, as is customary, the level of the latter is maintained approximately constant. (Water is added to the vats at intervals in order to replace that lost by evaporation.) The second action will cause a decrease in the acidity and an increase in the density of the solutions, owing to a consumption of sulphuric acid with the production of a corresponding amount of copper sulphate. In all cases thus far observed the latter effect is predominant. The exact causes of this consumption of acid and the best methods of reducing or eliminating it are now the subjects of investigation by the bureau.

In general it is necessary at intervals to determine and correct the composition of the solutions. The mere determination of the density of such solutions, whether with Beaume or specific-gravity hydrometer, is not sufficient to fix their composition. If, however, the density of the solutions and also the amount of free sulphuric acid present are determined, the composition is fixed. Thus, for example, a solution with a specific gravity of 1.16 (20 deg. Beaume) and containing 45 grams per liter (6 oz. per gallon) of free sulphuric acid has a perfectly definite and reproducible composition. The above figures do not, to be sure, indicate the amount of copper sulphate present in such a solution, but this is of no consequence to an electrotyper except when he is

preparing a new solution. For such cases tables showing the amount of copper sulphate required to produce solutions of any desired density, with any specified acid content, would be desirable, and will probably be prepared.

The bureau is not yet able to recommend any composition of the solutions as best adapted to any given conditions of operation. In various commercial solutions thus far tested the specific gravity ranges from 1.12 (15.5 deg. Beaume) to 1.20 (24.2 deg. Beaume) and the acidity from 25 g/l (3.3 oz./gal.) to 90 g/l (12 oz./gal.). In general the lower the voltage employed the more acid is required to produce a given current strength and rate of deposition, and vice versa. For the present, each operator should find a composition of solution which will give him satisfactory results under his conditions, and maintain it as nearly constant as possible by adjusting the density and acidity of the solutions at regular intervals (e.g., once a week) by the methods described in the following sections.

2—DENSITY

Before testing the solutions they should always be adjusted to the normal level of the vats by the addition of water if necessary, and thoroughly mixed. The hydrometer should always be read in the same way, preferably by floating it in a glass jar or cylinder containing the solution. By placing the eye slightly below the level of the solution, and then gradually raising the eye, the surface, first seen as an ellipse, becomes a straight line, the intersection of which with the hydrometer scale should be taken as the reading of the hydrometer. For practical purposes, and especially for comparison, the readings will usually be sufficiently accurate if made by observing the hydrometer scale above the surface of the liquid. The density should always be taken at approximately the same temperature, preferably 60 deg. F.

Having determined the density of the solution (which will usually be found to be higher than is desired), it may be adjusted to the desired density by the following method, based on the assumption that the excess density of the solution (above that of water) is approximately proportional to the content of the dissolved substances.

(*a*) *Specific Gravity.*—If a specific-gravity hydrometer is employed, divide the difference between the observed and desired specific gravities by the difference between the observed specific gravity and the specific gravity of water, which is 1.000. The result is the percentage of the solution which should be replaced with water.

EXAMPLE

Observed sp. gr.	1.179	Observed sp. gr.	1.179
Desired sp. gr.	1.160	Sp. gr. of water	1.000
Difference	.019	Difference	.179

$$\frac{0.019}{0.179} \text{ or } \frac{19}{179} = 10.6 \text{ per cent.}$$

Therefore, replace with water 10.6 per cent of the solution, or 10.6 gal. for every 100 gal. in the vat.

(*b*) *Beaume.*—If a Beaume hydrometer is used, the calculations are even simpler, and for practical purposes are sufficiently accurate. In this case we simply divide the difference between the observed and desired density, in degrees Beaume, by the observed degrees Beaume, to obtain the percentage of the solution to be replaced with water.[1]

Example

	Deg.
Observed degrees Beaume	22
Desired degrees Beaume	20
Difference	2

$$\frac{2^\circ}{22^\circ} = \frac{1}{11} = 9.1 \text{ per cent}$$

3—DETERMINATION OF ACIDITY

(*a*) *Principle.*—The amount of free sulphuric acid in the solution is determined by measuring the volume of an alkali solution of known strength which is required to neutralize the acid present in a measured volume of the solution. An indicator (methyl orange) is added to the solution in order to show, by its change in color, when all the acid is neutralized by the alkali. The method as applied to such solutions is not original, having been published by Wogrinz[2] in 1913. Even before that time it was used in a few electrotyping establishments in this country.[3]

(*b*) *Apparatus.*—The only essential pieces of apparatus for making this test are a pipette to measure the copper sulphate solution, a burette to measure the standard alkali, and a few bottles. Fig. 1 illustrates a form of apparatus that has been found convenient in this work. Doubtless many other forms of reservoir burettes will be found equally suitable. This apparatus and also the necessary solutions can doubtless be secured for a moderate charge from any local chemist or chemical supply house.

(*c*) *Solutions.*—(1) *Alkali.*—A sodium hydroxide (caustic soda) solution of any *known* and convenient strength may be employed. In a preliminary circular of the Bureau a solution prepared of a strength (0.61 normal) equivalent in the titration to 3.0 grams per liter of sulphuric acid was suggested. In view of the greater ease of securing a normal solution of sodium hydroxide the Bureau now recommends the use of a *normal*[4] solution. One cubic centimeter (1 cc) of such a solution will neutralize 0.049 gram of sulphuric acid. If, therefore, a sample of 10 cc (or 1/100 of a liter) of the copper solution be titrated, each cubic centimeter of the sodium hydroxide required is equivalent to 4.9 grams per liter (or for most practical purposes 5 g/l or 0.67 oz./gal.) of sulphuric acid. Solutions of other strength may be employed, provided the calculations be correspondingly changed. Since the sodium hyroxide may change in strength on standing (owing to its attacking the glass of the container) it should either be renewed, or restandardized by a chemist, at intervals of about six months.

(2) *Methyl orange* solution, containing one part of methyl orange in 5000 parts of water, is used as an indicator, i.e., it changes color when all the sulphuric acid is neutralized.

(*d*) *Titration.*—To carry out the titration, measure with a pipette 10 cc of the copper sulphate solution to be tested (after the bath has been adjusted to the desired specific gravity and thoroughly mixed) and run it into a small flask. Add to it about 2 cc of the methyl orange solution. To adjust the sodium hydroxide solution to the zero mark in the burette, turn the center stopcock so that the burette is connected with the stock bottle, and with the bulb pump the solution until it is above the zero mark, and then shut off this stopcock. Next turn the side stopcock and allow the solution to run into any convenient vessel (for waste) until all air is displaced from the side tube and the lower edge of the curved surface of the liquid is just at the zero mark. Now run the sodium hydroxide solution into the copper sulphate solution slowly, with constant shaking, until

[1] Since 22 degrees Beaume = 1.179 sp. gr., and 20 degrees Beaume = 1.160 sp. gr., the results in the above examples by the two methods of calculation should be the same, instead of 10.6 per cent and 9.1 per cent, respectively. The observed difference, which is due to the assumption that the readings of the Beaume scale are proportional to the specific gravity, is negligible in practical work, being equivalent to a difference of only 0.003 in the resultant specific gravity. Whichever instrument is used, there is no advantage in a very accurate adjustment of the density, since this will be somewhat altered by any subsequent addition of sulphuric acid.

[2] Chem. Ztg., 37, p. 869; 1913.

[3] Private communication from Wilson Yerger.

[4] This should not be confused with a *decinormal* solution, which is often used in scientific and technical work.

the violet color of the solution just disappears. If a decided green color or appreciable precipitate appears, too much alkali has been added and a new portion should be titrated.

Note the position of the lower edge of the curve at the end of the titration. After completing the titrations, allow the burette to empty and put a *little* vaseline on the stopcocks.

(*e*) *Calculation.*—To find the number of grams per liter of sulphuric acid in the copper solution, multiply by *five* the number of cubic centimeters of alkali used in the above titration. To find the number of pounds of acid to be added for each 100 gal. in the bath, deduct the amount of sulphuric acid thus found from the prescribed content and multiply the result by 0.83, or practically 5 ÷ 6. (Since 1 gal. is equal to 3.79 liters, or 100 gal. equal 379 liters, we multiply by 379 the number of grams per liter required; and since there are 454 grams in 1 lb., we divide the last result by 454. For practical purposes, therefore, we multiply by 379 ÷ 454 or 0.83.)

For any given capacity of vat the correct factor can be readily determined.

Example.—Suppose 10 cc of the copper solution requires 9 cc of the alkali in the titration. Then the solution contains $9 \times 5 = 45$ grams per liter of acid. If, for example, we desire to have present in the solution 60 grams per liter of acid, it is necessary to add $60 - 45$ or 15 grams of acid for each liter of the solution. For a vat holding 100 gal. we must add 15×0.83 (or $15 \times 5 \div 6$) = 12.5 lb. of acid. Or, if the vat holds, for instance, 180 gal., we use the factor $180 \div 100 \times 0.83 = 1.49$; i.e., we must add $15 \times 1.49 = 22.4$ lb. of acid.

(*f*) *Notes.*—(1) In the above operations and calculations extreme accuracy is not required, since all that can be accomplished is to keep the composition of the solutions approximately constant. The chief value of such tests will be to enable the operator to avoid obtaining defective work, or, in cases where the work may prove defective, to determine immediately whether the composition of the solution or some other condition is at fault.

(2) A permanent record of all titrations and of all changes in or additions to the solutions should be kept. Such records will ultimately furnish valuable information regarding the operation of the bath.

The circular is concluded by some brief non-committal notes on nickel electrotyping solutions.

The **Scientific Specialties Company**, of 17 Madison Avenue, New York City, has perfected arrangements with the C. P. Link Company to act as distributors for the Link water still (described in an article on page 796 of our issue of December, 1914). The Scientific Specialties Company will also act as the agents for a new hard porcelain of Bauscher make with excellent acid, alkali and heat-resisting qualities.

Coal Drier.—The Link-Belt Company has just issued a pamphlet on the Wendell drier in which the drying of washed coal for coking purposes is carried out by centrifugal force in automatic and continuous operation.

The **Chapman Engineering Company**, Mt. Vernon, Ohio, report considerable improvement in the gas producer trade. They have recently received an order from the Irtysh Corporation, London, England, for two 10 ft. Chapman rotary full mechanical producers. These will be installed in their zinc smelter at Ekibastous, Siberia. The New Jersey Zinc Co. have ordered four producers of this same type for their Palmerton, Pa., plant. These producers will gasify anthracite coal.

The Tapalog, a New Multiple Record Pyrometer Recorder

The Wilson-Maeulen Company, 1 East 42nd Street, New York City, has just placed on the market a new pyrometer recorder for multiple records, called the Tapalog, which embodies various radically new and decidedly interesting features.

Fig. 1 shows the tapalog operating in connection with four thermocouples.

Fig. 2 shows how in the tapalog the carriage sup-

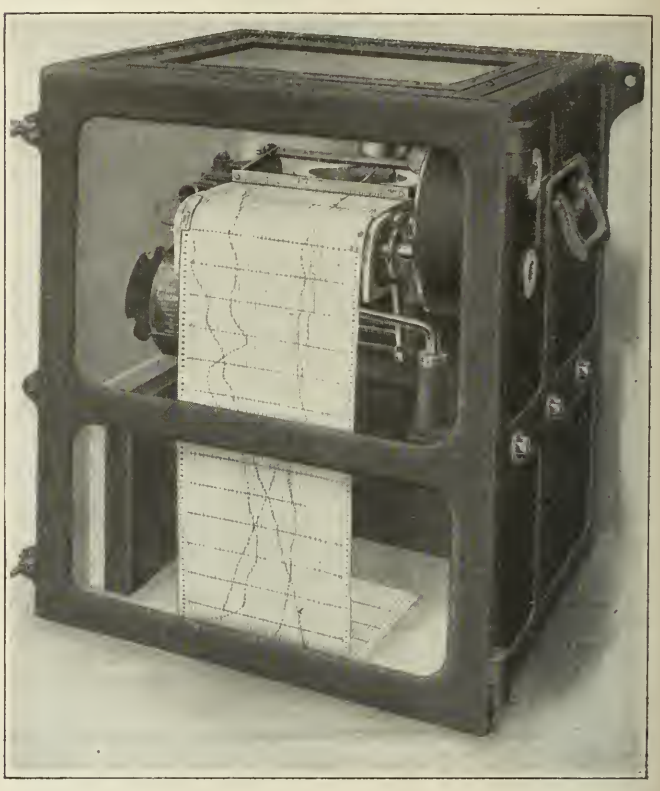


FIG. 1—THE TAPALOG OPERATING IN CONNECTION WITH FOUR THERMOCOUPLES

porting the record materials is lowered for change of paper and ink ribbon.

Fig. 3 shows the tapalog with paper roll and typewriter ribbon removed and discloses the straight edge which is the platen that results in rectangular coordinates for the record paper.

The idea of using a multi-color typewriter ribbon is new, and the idea of having the carriage, containing the ribbon and record paper, pivoted so as to swing down and away from the galvanometer is a great convenience to the operator, as the roll of paper can be taken out and the typewriter ribbon changed without having to carry on these operations in close proximity to the galvanometer.

By a crank motion the pulleys, around which the typewriter ribbon rotates, oscillate back and forth at right angles to the belt-like traverse of the ribbon so that the wear is distributed in somewhat of a sine wave. In addition to this oscillation, there is also the lateral shift, bringing the new color band into position synchronously with the rotation of the switch which connects the tapalog to another thermocouple.

In its simplest form, the tapalog has a single color band and operates with only one thermocouple, but it is generally furnished with the multi-record attachment shown at the left of photograph Fig. 2, and it will then take records of two, three or four thermo-

couples, each in a distinctive color, these colors being red, black, green, and violet.

An electromagnet, which operates the automatic switch, also operates the periodic depression of the boom carrying the indicating scale and which gives the blow that makes the dot and which boom lifts

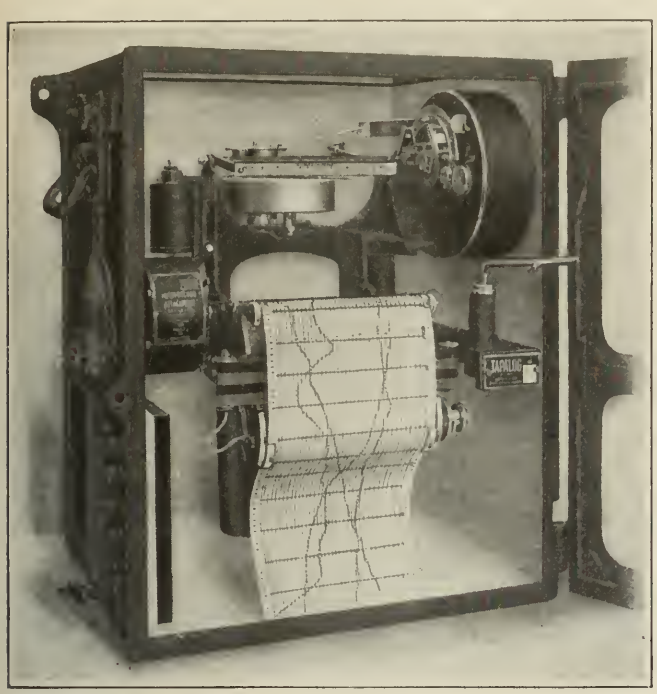


FIG. 2—THE TAPALOG WITH CARRIAGE SUPPORTING RECORD MATERIALS LOWERED FOR CHANGE OF PAPER AND INK RIBBON

slowly, leaving the pointer free to swing to its true position between the time of dotting. One dot is made every twelve seconds.

The clock has practically no work to do other than furnish the time. Actually the chopper boom is over-counterbalanced so that it tends to rise and is held

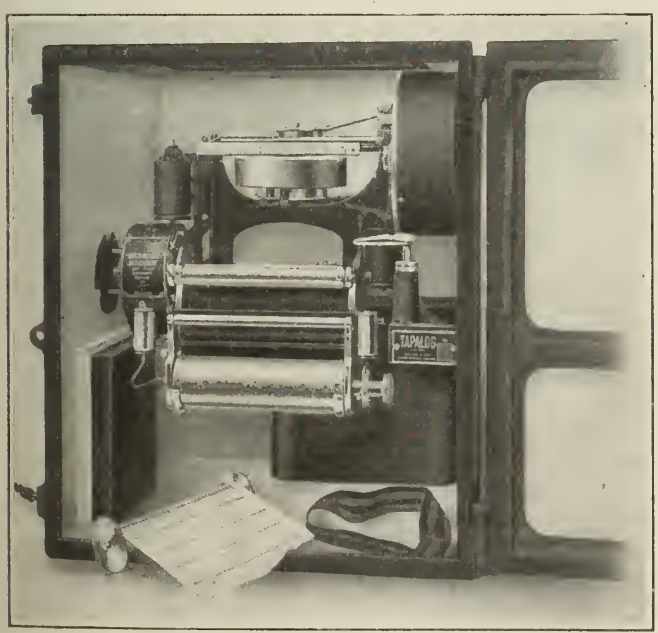


FIG. 3—THE TAPALOG WITH PAPER ROLL AND TYPEWRITER REMOVED, DISCLOSING STRAIT EDGE WHICH IS THE PLATEN THAT RESULTS IN RECTANGULAR CO-ORDINATES FOR THE RECORD PAPER

back by the clock, so that it almost drives the clock but in a way that does not disturb the good timing by the clock. This is a radically new feature in a clock-controlled recording instrument.

There is a convenient zero adjuster, accessible from the front, a start and stop lever for the clock, and a lever on the multi-record attachment enables one to instantly change the multiple recorder to a single-record type operating continuously on one thermocouple.

The instrument is in a metallic dustproof case which is even dustproof at the clock keyholes. All insulating pieces are bakelite instead of fibre or rubber.

The record paper is a good tracing paper, and the record is taken on the under side and is practically as clearly visible on one side as the other. By having the typewriter ribbon on the under side, the record is visible instantly after being made and the pointer never comes in contact with the inking material and stays clean and frictionless. The record is manifestly in shape for blue printing. The width of the record paper is 6 in. and the actual calibration is $5^1/_4$ in., and the advance of the paper is 1 in. an hour.

A two-record instrument, for instance, can be changed to a four-record instrument by the user in less than a minute by simply slipping on a four-color ribbon in place of the two-color ribbon and by making the proper connections at the binding posts on the outside of the case.

While this is a new instrument, quite a number of them are now in service, and they are taking excellent records to the entire satisfaction of the operators. Galvanometers of different sensitivity are to be used in the tapalog for different temperature ranges and different kinds of thermocouples.

The electrical contacts have been given most careful attention in the Tapalog. The contact which closes the battery circuit for operating the automatic switch and the depressing boom is platinum-rhodium on platinum, and the contact is operated by a blow from power furnished by the electromagnet itself and not by the clock; in fact, there are two of these contacts in parallel, and in addition there is provided a rotary double scraping contact, also platinum, so that it is hard to conceive of the possibility of the electric circuit not be properly closed. In the automatic switch the brush contacts are platinum-rhodium sliding over gold wires mounted on the periphery of bakelite disks.

A Flourishing German Smoke Abatement Society

BY JOHN B. C. KERSHAW

The tenth annual report of the Hamburg *Verein für Feuerungsbetrieb und Rauchbekämpfung*, which has recently made its appearance, is like all its predecessors, a valuable and instructive publication. As the Hamburg society is carrying out what is probably the most successful practical work in the cause of smoke abatement in Europe, some account of its organiaztion and activities may prove of interest.

The society was founded in the year 1902 by a group of Hamburg manufacturers, who were convinced that some better system of control of their boiler and heating plant was desirable than the one customary up to that date. Large firms with unlimited resources and a huge coal bill could afford to employ chemical engineers to devote their whole energies and time to the scientific management of the heating and steam raising plant. The smaller power-users in the city were handicapped, however, by the difficulty of obtaining expert control or management of one or two boilers or furnaces, and

as a result of this difficulty the power plant in small factories was left too often entirely in the charge of a fireman or engineer whose scientific knowledge and technical training was quite inadequate to the demands made upon it. Smoke, inefficiency and waste were the natural accompaniments of this state of things, and it was to remedy these that the Hamburg *Verein für Feuerungsbetrieb und Rauchbekämpfung* was founded.

How successful the society has been in its own particular sphere of operations is shown by Fig. 1, which records in diagrammatic form the growth of the society in the various classes of membership and in the number of boilers placed under its charge since its birth, twelve years ago. The apparent set-back met with in 1911 was due to the foundation of a branch society in Helsingfors, Finland, and to the transfer to the register of the new society of some of the members and boilers of the parent organization. It is satisfactory to note that the curves both for membership and for boilers have once again assumed an upward trend, and that on April 1, 1914, the Hamburg society had 500 members and 1744 boilers and other heating installations on its register.

The work of the society is controlled by a committee of seven members, elected annually. The technical and

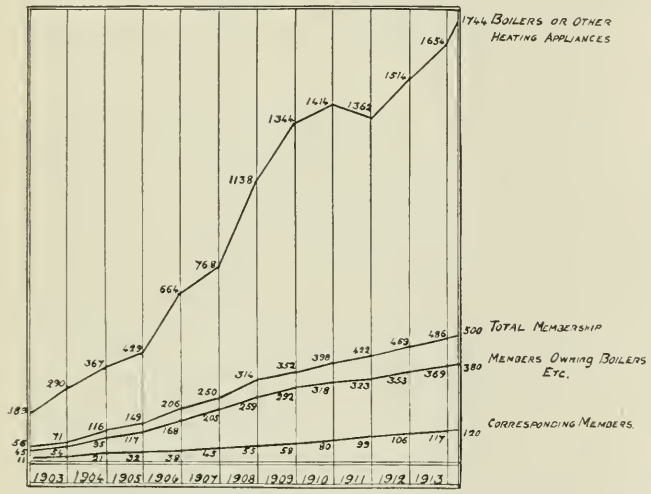


FIG. 1—GROWTH OF THE HAMBURG SOCIETY IN THE PERIOD 1902-1914

scientific work is undertaken by the staff of experts retained by the society for this special purpose. At the date of the last report this staff consisted of a chief engineer, three assistant engineers, five instructors for firemen and three clerks—while for special steam-raising and other trials additional assistance had been employed. The chief engineer attends the committee meetings and takes part in the discussions relating to the work of the society. The funds of the society are drawn from three sources: From the annual subscriptions of its members; from payment for special work and reports for its members; from payments for outside work.

The society is thus entirely self-supporting and its success is dependent upon the value of the return it makes to its members for their contributions and fees.

The objects of the society, as set forth in the rules, are the attainment of the highest possible efficiency from the heating and boiler plants of its members with the least possible emission of smoke. To this end regular examination of these plants and of the methods of working them is undertaken by the expert staff of the society, and suggestions are made for improvements when such are required. The education and control of the firemen in the proper performance of their duties are also undertaken by the firemen-instructors on the staff of the society. Comparative tests of fuel and tests of smoke prevention devices and other appliances of a similar character are also carried out by the expert staff and the results are circulated among the members of the society.

Each boiler or heating plant, when brought under the control of the expert staff of the society, is tested at the earliest possible date, and a written report upon the results of the examination is submitted to the owner. Should the firing have proved inefficient one of the firemen instructors is sent to the works to give practical instruction to the firemen employed there, and tests of

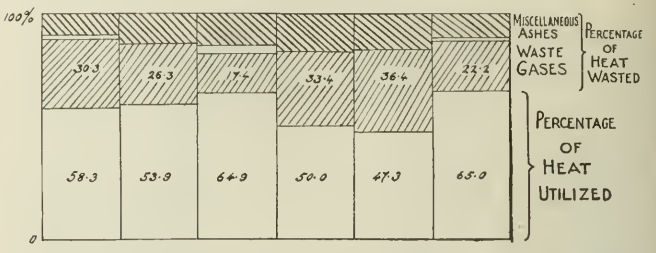


FIG. 2—RESULTS OF THE FIRST TRIALS BEFORE SPECIAL TRAINING OF STOKER

the plant are made at intervals until this fault is remedied. Defects in design are similarly dealt with.

The annual subscription to the society for members without any boiler or heating plant (fördernde mitgliedër) is 20 marks ($5). Members having boilers or furnaces which they desire to place under the control of the experts of the society pay a further 20 marks ($5) annually for each boiler or furnace.

The extra charges for tests and reports are based upon the time spent upon them and the number of experts employed. Engineers are charged for at the rate of 20 marks ($5) per day and firemen-instructors at 5 marks ($1.25) per day. Special reports upon patented appliances are charged for at the customary rates; members receive a special discount of 30 per cent on these as compared with outsiders.

Turning now to a consideration of the practical results of the work carried on by the society, as recorded in the past annual reports, we find that great stress is laid upon the improvements in efficiency due to the training of the stokers in the proper performance of their duties and figures are given in every report showing

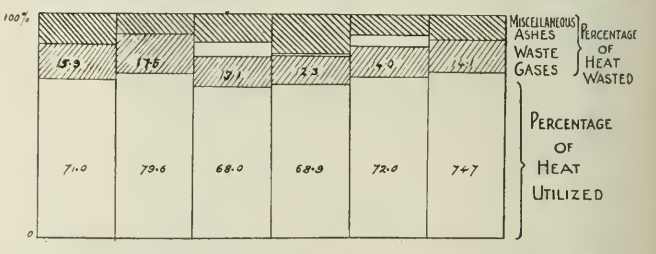


FIG. 3—RESULTS OF THE FIRST TRIALS AFTER SPECIAL TRAINING OF STOKER

gains in efficiency varying from 10 per cent to 20 per cent from this one cause alone. As examples of the gains which have followed from the society's control of boiler plants the two diagrams, Figs. 2 and 3 (taken from the 1912 report), are interesting, since they show in graphic form the results of tests on the same boilers before and after the engineers of the society had taken charge of the respective plants.

The heat loss in chimney gases, ashes, etc., is here seen to have varied between 35 per cent and 53 per cent when the boilers were working under the normal conditions, i.e., in charge of their usual stokers; while after

the society's expert staff had taken control the total heat losses were reduced to between 21 per cent and 32 per cent. The best efficiency recorded in these diagrams is that of No. 2 installation, with 79.6 per cent of the heat value of the fuel utilized in steam-raising, compared with only 59.9 per cent utilized before the transfer of the boiler plant to the company's charge. This represents a gain of 19.7 per cent in efficiency and a saving of 20 per cent on the coal bill.

It is most important to note that the society does not merely test each boiler or furnace plant once and then leave the stokers or engineers to their own devices again. The plant is visited, inspected and tested at regular intervals of time and by systematic instruction and oversight of the regular firemen at their work, an attempt is made to render permanent the gains shown by the first run under more scientific conditions. The staff of "instructors for firemen" have an important rôle to fill in this regular work of the society, for when any plant is not producing the results expected from it one or more of these expert firemen is sent and instruction and advice are given on the spot to the regular fireman of the plant. When necessary the expert fireman takes sole charge of the boilers and fires for an hour or two while the regular fireman looks on. This undoubtedly is the best way to train firemen in the practical side of their duties, for though evening classes and lectures have their value and place they can never be a satisfactory substitute for practical oral instruction given on the firing-plate of the boilers by a man who can handle a shovel as well as he can explain the chemistry of combustion.

Enough has been said above to indicate the general lines and methods of the Hamburg society's work and the results achieved and a small space may be devoted now to the special investigations referred to in the last report. For the expert staff of the society in addition to its regular control of the steam-raising and heating plant of its members is always carrying on special tests of new forms of grate or of some other accessory of boiler plant. Latterly a very large number of comparative tests have been made with mechanical stokers of both the "sprinkler" and "coker" types. The results of these special tests are included in the annual reports, and a complete set of past reports of the Hamburg society is therefore a most valuable addition to the reference library of all consulting engineers who are specially interested in boilers and steam-raising plant.

The special investigations that are dealt with in the tenth report are the following:

1. Trials and tests with mechanical stokers: (*a*) Sprinkler type; Axer; Dingler, "Man," Weck, Mückner, Seyboth. (*b*) Chain-grate stokers. Babcock & Wilcox, "Bamag," "Man," Steinmüller.
2. Trials and tests with regulators of secondary air supply to hand-fired boilers.
3. Tests of water-cooled hollow bar. German "Prometheus" grate.
4. Ships boilers and their methods of firing; cylindrical boilers.
5. Artificial draft for boilers.
6. Domestic heating appliances.
7. Results of fuel-tests.

With reference to the last subject in this list it may be stated that for the past three years the Hamburg society has taken considerable interest in the movement for purchasing fuel on a more scientific basis and that it has appointed Dr. Aufhauser, of the Thermo-Chemische Prüfungs-und Versuchs-Anstalt, in Hamburg, official fuel analyst for the society. A large number of members of the society take advantage of this arrangement to have regular samples taken and tested of their fuel supplies, and the last report of the Verein contains many hundreds of test results of the fuel samples taken in 1913 and in preceding years. As the fuels are classified under the county or district from which they come and more than one-half the tests refer to English and Scotch shipping coals, this appendix to the report is of more than local interest and value.

Further Notes on the Refractory Properties of Zirconia

BY H. CONRAD MEYER

The remarkable heat-resisting properties of zirconia have been known for many years, but it is only within the last few months that serious attention has been given in America to its possibilities in metallurgy and furnace technology. The reader is referred to an article appearing in this journal for a brief history and description of zirconia.[1] Heretofore, zirconia has been considered one of the rare oxides and hence of limited application. It is now being supplied, however, in commercial quantities, and in many instances, is now being used on an industrial scale. A free exchange of ideas among many investigators has rapidly advanced the technology of zirconia, and the writer hopes that the preliminary data here given may be of value to all those now working on this new refractory body. Many of the investigations have been carried out by the author, and numerous independent reports have been secured from private sources, for which due credit is given.

Analysis of Natural Zirconia

In the investigation of refractory substances, a complete chemical analysis is often found of value. The presence of alkalies, silica and iron oxide often plays an important part in the behavior of the material when subjected to high temperatures. The mean of three analyses of an average sample of natural zirconia is given herewith:

ZrO_2	84.1
SiO_2	7.74
Fe_2O_3	3.10
TiO_2	1.21
Al_2O_3	.66
Loss on ignition	2.72
	99.53

It will be noted from the above, that the only two oxides present which would be likely to cause a lowering of the melting point of the zirconium oxide, are silica and ferric oxide. The 1.21 per cent of titanium oxide present, may or may not exert a fluxing action at high temperatures, but the practice seems to be, in manufacturing most fire brick and refractory ware, to disregard this oxide entirely. The ignition loss consists mainly of moisture with a small percentage of organic matter.

Heat Tests on Zirconia[2]

An ore containing 84 per cent Zro_2, ground to 100 mesh and mixed with H_2O, molded easily into cones which kept their shape when burnt with little warpage or shrinkage to about the temperature of cone 35 (1830° C.). These tests on cooling show a slightly vitrified material with a smooth and fine-grained surface.

Zirconia mixed with a 5 and 15 per cent mixture of Bens Creek clay, in view of finding a suitable bonding material, and heated to a temperature over cone 31 (1750° C.), shows the 15 per cent tests to be in fair

[1] *Met. & Chem. Eng.*, Vol. 12, No. 12, page 791, Dec., 1914.
[2] Data taken from the results of three or more tests on separate mixtures by G. T. Stowe.

shape, that is, slightly vitrified, cracked and coarser grained, while the 5 per cent test is in good shape with a fine finish and very little shrinkage or warpage. A mixture of 5 and 15 per cent Warrior Ridge clay with the zirconia and heated to the temperature of about cone 32 (1770° C.) shows the 5 per cent mixture to be in excellent shape with a clean cone standing at the end of the test. The 15 per cent mixture does not hold up quite as well at the same heat.

A mixture consisting of 98 per cent 100-mesh zirconia and 2 per cent slacked lime worked into a plastic form with H_2O, showed a fusion point of about cone 30 (1730° C.). Further, this cone lost its shape by warping at least five cones before the mixtures with clay.

The mixtures on a whole were easily molded. The pure zirconia test cones seemed to have some plastic properties and held together very well, making a clean and sharp-edged cone.

The burnt product seems to be a likely refractory material, granting that the higher heat and flux standing properties make up for the advance in the cost of manufacturing the material in comparison with other refractory wares. The vitrified samples show a very hard and seemingly strong ware.

Of all the tests made, the 5 per cent mixture of Warrior Ridge clay with the zirconia seems to make the best bond; produces the best appearing samples before and after burning, the pure zirconia tests excepted, and those only as to heat tests.

Fire Shrinkage[3]

Small briquets of the following were carefully made, measuring 36 x 20 x 5 mm. These when thoroughly dried, were burnt at a temperature of approximately 1427° C. in a No. 2 muffle furnace supplied by the American Gas Furnace Company.

No. 1. Pure zirconium oxide (99 per cent ZrO_2).
No. 2. Wet ground zirconia (84 per cent ZrO_2).
No. 3. Zirconia (95 per cent ZrO_2).
No. 4. 93 grams of No. 3, and 7 grams Dry Branch kaolin.
No. 5. 60 grams zirconia, 80 mesh (84 per cent ZrO_2) and 40 grams wet ground zirconia.

Linear shrinkage at 2600 deg. F.:

No. 1..... 9 per cent.
No. 2..... 9 per cent.
No. 3..... 9 per cent.
No. 4.....12 per cent.
No. 5..... 3 per cent.

Briquet No. 1, made from pure zirconium oxide, analyzing about 99 per cent ZrO_2, yielded a sticky mass on mixing with water and was quite soft after drying. After burning No. 1 was still in a soft condition and could be readily scratched with the nail.

Briquet No. 2 consisted of natural zirconia carrying about 84 per cent ZrO_2, corresponding to the analysis given above. As indicated, this material was wet ground in a ball mill and thus reduced to an extremely fine state of subdivision. It was readily molded into shape. Firing rendered the material extremely dense and of a flint-like hardness. Several briquets were heated to redness and one end plunged into a beaker of water. This quenching test apparently left the material unaffected, as no cracks were developed.

Briquet No. 3 was made from 95 per cent zirconium oxide. This 95 per cent product was prepared on a small scale from the natural or 84 per cent zirconia. Most of the silica and nearly all of the iron were removed by this refining, which yielded a light gray product. After firing, the briquets presented a very dense structure and were extremely hard.

[3]Author's tests.

Briquet No. 4 shows the bad effect of even a small percentage of a very refractory china clay. Dry Branch kaolin is a pure white, washed clay, having a fusing point above 1790 deg. C.

Briquet No. 5 was made from a mixture of 60 grams coarse zirconia (material passing through an 80 mesh screen) and 40 grams water-ground zirconia, or material similar to No. 2. It will be noted that the shrinkage in this case was extremely low. The briquet, after firing, presented a rather coarse, porous texture, but possessed considerable tensile strength.

Whether these shrinkage figures would be greater at higher temperatures, it is difficult to say.

Selection of a Binder

The proper choice of a binder is a very important consideration, as the fusing point of the zirconia is influenced largely by the substance added as a bond. Phosphoric acid, sodium silicate, and lime were tried, but with indifferent success, and in many cases it was clearly apparent that such bonds were positively detrimental.

The following data were secured from a private source.[4] The tests were made in the form of small briquets measuring 1¼ x 1¼ x 4 in. in a steel mold. The material was rammed in place with considerable pressure. Five such tests were made as follows:

(1) Zirconia powder, bonded by 26.5 deg. Bé$MgCl_2$ solution (concentrated from salt bittern). Mixed to consistency of a stiff mud and rammed. Dried 5 days—100 deg. C. Dried 8 hours—150 deg. C. Heated gradually to bright red and exposed to temperature of 1600 deg. C in an electric arc furnace for two hours. The sample showed no fusion; corners sharp and hard; scratch glass; shrinkage slight; FeO and Fe adhere in molten condition; FeO showed corrosion; very dense; difficult to crack with bricklayer's hammer.

(2) Zirconia powder, 50 per cent; dead-burnt magnesia (electrically dead-burnt), 50 per cent; bonded by 26.5 deg. Bé $MgCl_2$ solution and mixed to hard, stiff mud and rammed. Dried same as 1. Heated to same temperature and for same time as 1. Fused to spongy mass, dark color. The fusion was evidently caused by iron oxide and silica.

(3) Zirconia powder, 10 per cent; dead-burnt magnesia, 88 per cent; 26.5 deg. Bé $MgCl_2$ solution, 2 per cent. Mixed to stiff mud and rammed. Dried and heated same as for 1. Hard, dense, compact brick; sharp, hard corners; positively no fusion; showed no corrosion by FeO; light brown color.

(4) Zirconia powder; bonded by 30 deg. Bé Na_2SiO_3 solution to form stiff mud and rammed. Dried and heated same as 1. No fusion; extremely hard, dense; interior appeared denser than exterior; slight crack in interior, probably due to moisture.

(5) Zirconia powder; bonded by small amount of water in form of vapor, mixed to stiff mud and rammed. Dried and heated same as for 1. Compares to properties of 1. Showed same FeO corrosion.

With the exception of 2, which fused, the samples showed:

(1) General corrosion by FeO in spots.
(2) Slight shrinkage.
(3) Withstood temperature changes from 500 deg. C. to 1600 deg. C., without any cracking or spalling.
(4) No contortion or deformation at high temperature.
(5) Precaution necessary in choosing suitable binder, and also care to be used in mixing with other refractory substances containing impurities as FeO, SiO_2, etc.

[4]R. C. Gosrow.

(6) Zirconia can be used equally with magnesia, and with less cost for linings, etc.

The results secured by Mr. Gosrow under test No. 3 appeared promising enough to warrant further investigation along this line. Preliminary tests indicate that magnesium chloride would be objectionable on a commercial scale. Hence, another binder was sought and ultimately found in water-ground zirconia. It was further considered that the dead-burnt magnesia (electrically dead-burnt) might be successfully replaced by ordinary calcined magnesite, such as is used for magnesite cement in flooring. This product carries about 93 per cent magnesium oxide, with a small percentage of carbon dioxide, calcium oxide and silica.

The following formulas were used[5] in the making of several small briquets which were carefully dried and burnt at a temperature of approximately 1427 deg. C. in a small muffle furnace:

FORMULA 3A

45 grams zirconia (ground to pass through 80 mesh screen).
45 grams magnesium oxide (calcined).
10 grams water-ground zirconia.

The briquets after burning were of a brownish yellow cast, with a rather loose texture, but quite resistant to abrasion and of a fair tensile strength. The fire shrinkage at the above temperature was approximately 8 per cent linear measurement. One of the briquets at a white heat was dropped in a beaker of water, but no cracks were developed and the material was apparently as solid as before quenching.

FORMULA 3B

72 grams zirconia (ground to pass through 80 mesh screen.)
18 grams magnesium oxide (calcined).
10 grams water-ground zirconia.

Briquets made from this formula had very much the appearance of those produced by formula 3A. The fire shrinkage was approximately the same. The specific gravity was, of course, higher, owing to the greater percentage of zirconia present. The results of these tests were considered rather encouraging, and further investigations are now under way. The strong objection to the use of the magnesium oxide, particularly the calcined product, is the fact that it has an extremely high shrinkage. This of course is not true of the costly electrically shrunk magnesium oxide, but the tendency would naturally be toward the use of the cheaper calcined oxide.

Fire Clay Bond

As will be noted under fire shrinkage, briquet No. 4, mixed with a 10 per cent bond of refractory clay, showed extremely high shrinkage. It was decided, however, to manufacture a few standard-size fire bricks, using a 5 per cent bond of Warrior Ridge clay, as mentioned above. The zirconia was ground to pass through an 80-mesh screen, and thoroughly mixed in a dry pan with 5 per cent of the aforementioned clay. The mass was slightly moistened and formed into bricks in the same manner as is pursued in the manufacture of silica or chrome bricks. After thoroughly drying, these bricks were burnt in a silica brick kiln, at an estimated temperature of at least 1649 deg. C.

No figures were secured as to the fire shrinkage, but even this small percentage of clay caused the bricks to soften at a temperature well below the fusion point of the natural zirconia. The standard bricks made from the material weighed on an average 11¼ lbs. each.

To determine the behavior of the material when in contact with carbon at high temperatures,[6] a brick was made a part of one side of the trough of a granular carbon resistance furnace, the rest of the trough being made of magnesite brick, all being backed up by fire brick. A pyrometer tube was put in so as to give the temperature of the surface of the brick, next the carbon resistor, and temperatures read with a Wanner pyrometer. In about one half hour after starting, the temperature was 1800 deg. C. ± 25 deg., and it was held between 1750 deg. and 1850 deg. C., averaging 1800 deg. C. ± 25 deg. for 1½ hours. The furnace was then torn apart. The zirconia brick was just nicely red on the back (2½ in. from the resistor), while the magnesite bricks were much redder. From this and from the temperature of the fire brick backing when felt from time to time, it is plain that zirconia has a considerably lower thermal conductivity than magnesite, and quite probably the lowest of any available material that will stand 1800 deg. C.

The brick when put in place, had a slight crack, and this increased a little on heating, but not very badly. Magnesite bricks on both sides of it were badly cracked. A slight shrinkage was noted on the hot face, and the surface of the zirconia brick was slightly pitted and spongy. The spongy layer was only about ⅛ in. thick. The magnesite bricks were considerably more acted upon by the carbon than the zirconia bricks, their surfaces being eaten away uniformly over ⅛ in. Hence, as regards the action of carbon on the hot brick, the zirconia brick appears superior to magnesite, but inferior to carborundum.

The zirconia brick was not supporting any weight, and only the inner face reached 1800 deg. C. The brick had not really fused nor flowed of its own weight, *i. e.*, it might not have failed under a "cone test" at 1800 deg. C. Yet when the brick was picked up with tongs, they sank into the hot face, under gentle pressure, to a depth of ½ in.

The face of the brick was very plastic, and though it had not really fused nor flowed out of shape, the fact that the brick as a whole kept its shape was due to the stiffening effect of the comparatively cold back of the brick. If the whole brick had reached 1800 deg. C. and had been under any pressure, as in a wall with other courses of bricks resting on it, it would certainly have been pressed out of shape.

It therefore appears that 1800 deg. C. is the upper limit at which this brick (zirconia bonded with Warrior Ridge clay) could be safely used. It is, of course, quite possible that a brick bonded with water-ground zirconia and free from clay bond, might be stiffer and stand up at a higher temperature.

Therefore, while this particular brick is not as refractory under furnace conditions as the reported melting point of zirconia would lead one to expect, it is still refractory enough to be classed among the half dozen highest refractories; while not entirely free from shrinking and cracking, its behavior in this respect is far better than magnesite, although not as good as carborundum. Its heat conductivity is apparently less than any other of our high refractories. Its behavior in contact with carbon, while not perfect, is not so bad but that it can probably be controlled.

Zirconia Crucibles and Similar Shapes

In the manufacture of crucibles, muffles, etc., from zirconia, it should always be borne in mind that the material has an extremely low thermal conductivity. Hence, the walls of the crucible or other shape must be considerably thinner than would be the case if clay were used. Owing to the high tensile strength of zirconia

[5] By J. R. Adams under author's supervision.

[6] The following data was contributed by an experienced investigator, who requests that his name be withheld.

when properly bonded and burnt at a sufficiently high temperature, it is possible to make such objects without the danger of breakage through handling. Another important consideration in the use of zirconia in crucibles is its resistance to fluxes and slags. It has been suggested that water-ground zirconia might prove very efficient as a lining for graphite crucibles. Shallow dishes, trays and small crucibles have been made experimentally by hydraulically pressing various mixtures of coarse zirconia bonded with water-ground material, producing ware of high tensile strength and of extreme thinness. Shallow dishes have been pressed in this way, having a diameter of 6 in. and maximum thickness of not over ⅜ in.

Although this article does not concern itself with the uses and applications of chemically pure oxide of zirconium, it is interesting to note that two patents have recently been granted for the manufacture of utensils and the like from the oxides of the rare earths, such as thorium, zirconium, etc.

While the foregoing results should not be accepted as final or conclusive, they apparently presage important industrial uses for this new refractory.

Laboratory, Foote Mineral Co.,
Philadelphia, Pa.

The Dedication of the New Building of the Mellon Institute

BY W. A. HAMOR*

The new $350,000 building which will form the permanent home of the Mellon Institute of Industrial Research and School of Specific Industries of the University of Pittsburgh, was formally dedicated on Feb. 26. This building, the gift of Messrs. Andrew William and Richard Beatty Mellon, of Pittsburgh, was especially designed for the needs of the institute; it is distinctly

THE NEW BUILDING OF THE MELLON INSTITUTE IN PITTSBURGH

modern in every respect and complete facilities are provided for the investigation of manufacturing problems and for conducting industrial research according to the practical system of co-operation between science and industry, founded by the late director of the institute, Robert Kennedy Duncan. By this system an industrialist having a problem requiring solution may become the donor of a fellowship by providing the salary of the researcher selected to carry out the investigation desired, the institute supplying every facility for the work—laboratory space, the necessary apparatus and supplies, library facilities and advice of a staff expert in industrial research, etc.

The new home of the Mellon Institute is a five-story and attic building. The basement contains seven rooms: the main storeroom, the boiler room, the electric-furnace room, a heavy-apparatus room, a room equipped for low-temperature work, the machine shop and the kitchen. On the first, the main floor, are located the general office, the director's suite, the office of the editorial department, the library, the office and laboratory of the assistant directors, the assembly hall, a special apparatus room and a dark-room laboratory. The second and third floors each contain ten large research laboratories and nine small ones; the fourth floor, which is not finished, will contain an identical number of laboratories as soon as the growth of the institute warrants its completion. At the present time twenty-three fellowships are in operation and forty research chemists are engaged in a study of the variety of industrial problems under investigation at the institute.

While the Mellon Institute possesses an endowment of its own and has its own board of trustees, it is an integral part of the University of Pittsburgh. The dedicatory ceremonies were accordingly held in conjunction with the annual Charter Day exercises of the University.

The chancellor of the university, Dr. Samuel Black McCormick, presided at the dedication ceremonies, which took place at 11 a. m. in Soldiers' Memorial Hall, in conjunction with the annual Charter Day exercises of the University. Following the address of the day by Dr. Rossiter Worthington Raymond on "Knowledge and Research," Dr. W. J. Holland, director of Carnegie Museum and formerly chancellor of the university, made the presentation speech in connection with the dedication of the Mellon Institute, on behalf of Andrew W. and Richard B. Mellon, the donors. After a tribute to the generosity of the Messrs. Mellon, Dr. Holland said in part:

"In a certain sense this building is a memorial to Robert Kennedy Duncan. On one side of the entrance is a bronze slab inscribed with the name of Thomas Mellon; on the other side of the entrance is a bronze slab inscribed with the name of Robert Kennedy Duncan. But this splendid edifice erected upon the campus of our University is more than a cenotaph. It not merely commemorates the names and careers of those of whom I have spoken, but it is intended to serve as the seat of advanced inquiries along scientific lines, which will tend to the promotion not merely of intellectual culture, but of industrial success, and that not merely in this great 'workshop of the world,' where it is located, but throughout the land. In creating this institution our dear friends have been actuated by a high and intelligent purpose. Large experience in great industrial enterprise has taught them the importance of chemistry and physics in their application to the industrial arts, and they feel, that, wonderful as has been the progress made within the last century, there are untold mysteries in nature, which have not yet been revealed, but which, if uncovered, are capable of being used for the welfare of mankind. And so they have created and are today placing in the custody of you, gentlemen of the Board of Trustees, this institution, which is capable of becoming, when wisely and intelligently administered, a mighty implement for the advancement of human welfare."

Dr. George Hubbard Clapp, president of the board of trustees of the University, delivered the speech of acceptance. He expressed appreciation of the gift and understanding of the importance of the work for which the building has been erected.

The final ceremony of the exercises was the conferring of fifteen honorary degrees. The degree of Doctor of Laws was conferred on Edward Williams Morley, John Ulric Nef, Arthur Amos Noyes, Rossiter Worthington Raymond, Ira Remsen and Theodore William Richards.

The degree of Doctor of Science was conferred on John Jacob Abel, George Hubbard Clapp, Elbert Henry Gary, John Hays Hammond and Henry Marion Howe.

The degree of Doctor of Chemical Engineering was conferred on William Hultz Walker, Milton C. Whitaker

*Published by permission of Dr. Raymond F. Bacon, Director of the Mellon Institute.

and the degree of Doctor of Chemistry on Charles Lathrop Parsons and Edgar Fahs Smith.

Immediately after the close of the dedicatory exercises, the trustees, faculty and guests of the University met at a luncheon in the University Club. The remainder of the afternoon was devoted to an inspection of the new building of the Mellon Institute.

The recipients of honorary degrees were the guests of the University at the annual alumni banquet held at the Schenley Hotel from 6 to 8:30 p. m. The speakers at this dinner were Dr. Raymond F. Bacon, director of the Mellon Institute, who responded to "The Mellon Institute"; Dr. Walthor Biddle, who gave an historical sketch of the department of chemistry of the University; Hon. Elbert H. Gary, chairman of the United States Steel Corporation; Dr. Theodore William Richards, who spoke on "The Practical Use of Research in Pure Science" and extended Harvard's congratulations to Pittsburgh upon the acquisition of the Mellon Institute; and Chancellor Samuel Black McCormick, who completed the toast list with an eloquent response to "The University," in which he stated that the gift of the Mellon Institute had placed a great responsibility upon the University of Pittsburgh as well as having been a priceless acquisition; that the University was ready to meet the responsibility and, he felt sure, would show the donors and the country at large that it would make the most of the great benefaction.

After the banquet the new building of the Mellon Institute was thrown open for a reception of friends of the institute. The rooms of the main floor were used for the reception, although the entire building was open for inspection. On the evening of Feb. 27, the first Mellon lecture was delivered by Prof. John Jacob Abel, of Johns Hopkins University, in the assembly hall of the institute; Dr. Abel's subject was "Experimental and Chemical Studies of the Blood and Their Bearing on Medicine."

Personal

Mr. **T. A. Bennett,** who for the past five years has had charge of the conveyor and elevator belt sales of the B. F. Goodrich Company, Akron, Ohio, is severing his connection with the Goodrich Company on March 1st, to become the assistant to the general sales manager of the New Jersey Zinc Company, with offices in New York City. Mr. Bennett will be succeeded by Mr. **J. D. Mooney,** formerly special mining representative for the Goodrich Company.

Mr. **O. M. Bilharz** has resigned his position as technical manager for the St. Joe and Doe Run lead companies in southeastern Missouri.

Dr. John C. Branner, president of the Leland Stanford, Jr., University, Cal., has resigned to take effect July 31, 1915.

C. F. Burgess Laboratories is the new name of the Northern Chemical Engineering Laboratories of Madison, Wis. There is no change in management or ownership, and the concern of which C. F. Burgess, formerly professor of the University of Wisconsin, is president, will continue as heretofore its practice in chemical engineering, research, and industrial development.

Mr. **Arthur Crowfoot** has been appointed superintendent of the concentrator of the Arizona Copper Co., Morenci, Ariz. He was formerly engaged in various capacities at the Boston & Montana reduction works of the Anaconda Copper Mining Co.

Dr. Carl Hering, of Philadelphia, Pa., has been elected a Fellow of the Association for the Advancement of Science.

Mr. **V. D. Howbert** was recently elected president of the Colorado School of Mines Scientific Society, a student organization. C. E. Carstens is vice-president and F. E. Briber secretary.

Dr. W. C. Huntington has been appointed commercial agent in charge of the Chicago branch of the Bureau of Foreign and Domestic Commerce. He succeeds **Mr. H. H. Garver,** who has accepted the position of foreign trade commissioner of the Chicago Association of America.

Mr. **W. J. Kee, Jr.,** for the past four years superintendent of the Argentine acid plant of the National Zinc Company (formerly the United Zinc & Chemical Company), has resigned to become connected with the new acid plant designed by Mr. Utley Wedge for the Anaconda Copper Company, Anaconda, Mont.

Mr. **Edward W. Lawler,** for many years with the Hardinge Conical Mill Co., the Abbe Engineering Co., and other concerns, is now connected as sales engineer with the Jeffries Mfg. Co., with headquarters at 77 Warren Street, New York City.

Mr. **John L. Malm** has returned to Denver from a professional trip to Chicago.

Ricketts & Banks, New York, have dissolved their copartnership by mutual consent, and each will continue separately in business as mining, metallurgical and chemical engineers. **Ricketts & Co.** will be located at 80 Maiden Lane, and **Dr. John H. Banks** at 61 Broadway.

Mr. **L. T. Ticka** has resigned his position as mechanical superintendent of the International Smelting Company, Tooele, Utah, to become the mechanical superintendent and engineer for the St. Joseph Lead Company, Bonne Terre, Mo.

Mr. **H. E. Tuttle** has severed his connection with the Edgar Zinc Company and is with the Fink Furnace Company, Chicago.

Obituary

Frank L. Clerc died in Denver, Colo., March 9, 1915. Mr. Clerc had long been identified with the zinc industry and was well and favorably known as a metallurgist in that branch of ore treatment. Although he had not been engaged in active practice in recent years, his interest in his chosen line of work did not abate, and he continued his studies and researches practically up to the time of his death. As a contributor to technical literature he was known to a wide circle of metallurgists. Shortly before he returned to Denver from an eastern trip during the winter, he was engaged in gathering together his contributions which had appeared in this journal and elsewhere, with the idea of republishing them in book form. In recent years he had been much interested in the metallurgical problems confronting the producers of low-grade carbonate and silicate zinc ores at Leadville. On this subject he proposed a number of methods of procedure, bearing particularly on igneous concentration. He also invented a form of furnace that he considered specially applicable to the reduction of the zinc oxide that would result from fire concentration of low-grade ores.

Mr. Clerc was born in Pennsylvania on February 22, 1851. He studied and graduated at Lehigh University and came west, finding a field for his activities in the zinc district of Missouri and later in New Jersey. At different times he was identified with the faculties of the Massachusetts Institute of Technology and the Colorado School of Mines. He is survived by two sisters, one of whom lives in Phillipsburg, Pa., and the other in Wilton, Conn.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Electroplating Alloys

273,324, March 6, 1883, Joseph M. Thomas, of Auburn, N. Y., assignor to Byron C. Smith, of same place.

Relates to electrodepositing brass upon steel, malleable, cast or wrought iron, or upon tin, lead, bismuth, type or britannia metal, from a solution prepared as follows: 1 ounce (avoirdupois) of crystallized acetate of copper is dissolved in 8 ounces (liquid measure) of ammonia water of 26 deg. B.; in 1 gal. of distilled or rain water, at 165 deg. Fahr., is now dissolved 18 ounces (avoirdupois) potassium cyanide; to this cyanide solution is now added 2 ounces crystallized acetate of zinc, with stirring until dissolved; the acetate of copper and ammonia solution is now added and lastly ¼ ounce (liquid measure) commercial hydrocyanic acid. The solution thus prepared is heated to about 165 deg. Fahr. and used as the electrolyte with either copper and zinc or brass as anode. The color of the brass deposit is determined by the current strength; a strong smooth current is recommended.

477,350, June 21, 1892, Edward T. Burrowes, of Portland, Maine.

Relates to electroplating wire-screen-cloth made of brass, copper or composition or other bright smoothly finished wire, so as to diminish its excessive brightness, toning it down to a darker and more subdued color, rendering it less conspicuous and better adapted for house-screen use. The electrolyte is made by dissolving 30 lb. of copper sulphate, 1½ ounce caustic potash, 10 lb. zinc sulphate, 6 ounces tin chloride, 5 lb. salammoniac and 8 ounces muriate of iron. This is deposited electrically by means of an anode composed of 8 lb. of copper and 1½ lb. each of tin and zinc. The plating process changes the bright-wire screening to a fine dark-brown color resembling statuary bronze, which is said to be permanent and not liable to be affected by the atmosphere.

487,176, Nov. 29, 1892, Sherard Osborn Cowper-Coles, of London, England, assignor of one-half to the London Metallurgical Company, Ltd., of same place.

Relates to electrodepositing upon metals or other suitable objects an alloy better adapted than silver to resist the tarnishing influences of the atmosphere. The alloy consists of zinc and silver, or cadmium and silver, or zinc, cadmium and silver; the proportions varying from 35 per cent to 25 per cent, or less, of the zinc or cadmium; or a cheaper alloy may be made with from 40 per cent to 90 per cent of the base metal. The electrolyte is prepared as follows: A suitable quantity of cyanide of zinc or cadmium is dissolved in a solution of cyanide of potassium, so as to form a double salt having an excess of cyanide of potassium. To this solution is added a small quantity of the double salt of the cyanides of potassium and silver. The electrolyte thus prepared may be used hot or cold. An anode of approximately the composition of the alloy deposit desired is employed, the hardness of the alloy varying with its composition. (See also his later patent, No. 512,160.)

512,160, Jan. 2, 1894, Sherard Osborn Cowper-Coles, of London, England, assignor to the London Metallurgical Company, Ltd., of same place.

Relates to the alloy deposit produced by the process described in his patent, No. 487,176, which should also be consulted. The alloy consists of silver and cadmium, silver and zinc, or silver, cadmium and zinc or any other known metal or metals, other than indium, having a specific gravity between 6.5 and 9, and boiling at a temperature between 710 deg. C. and 1045 deg. C., these alloys being employed with or without the addition of any or all of nickel, cobalt, tin and chromium. The anodes employed in the electrodeposition may be carbon, lead or platinum or of an alloy similar to that to be deposited. The electrolyte may be composed of compounds of silver dissolved in water or in alkaline cyanides, or alkalies or other bases, and may be mixed with solutions of compounds of zinc or cadmium, or of other metals of the alloy to be deposited; the electrolyte may also contain salts of the alkali and alkaline earth metals.

543,824, July 30, 1895, Henry J. Altman, of New York, N. Y., assignor of one-half to Max H. Fischer, of same place.

Relates to electrodepositing an alloy coating consisting of platinum with another metal or metals having a specific gravity of between 2.6 and 9, except manganese, antimony and chromium, which are not suited to his purposes. The preferred alloy consists of platinum and nickel, with about 1 per cent platinum; or may consist of a larger proportion, as one part platinum and three parts of nickel. The alloy deposit forms a brilliant coating resembling silver, but less liable to tarnish or corrode. The electrolyte contains the metals to be deposited as salts and is made by dissolving separately 12 ounces of nickel and ammonium sulphate in 7 pints of water, ¼ ounce of tetrachloride of platinum in ½ pint of water, 1/6 ounce of caustic soda in ½ pint of water; the caustic soda solution is added to the platinum solution and to the mixture is added 1¼ ounces of ethylamine or its equivalent. To this mixture is then added the nickel solution and then 1½ ounces of sodium chloride dissolved in water is added. The anode used preferably has the composition of the coating desired or may be of platinum or carbon, etc. For alloys of different composition, the proportions of the salts should be varied accordingly. In place of ethylamine there may be used any other organic base containing nitrogen, as methylamine, pyridin, etc.

563,723, July 14, 1896, Hans Alexander, of Berlin, Germany, assignor to Louis Potthoff, of Long Island City, N. Y.

This patent was reissued, No. 11,624, dated Aug. 3, 1897. It relates to plating iron or steel with a coating of zinc, as a substitute for the galvanizing of iron by molten zinc. An electrolyte containing a basic aluminium salt is made as follows: To a solution containing in 100 parts of water from 5 per cent to 8 per cent of chloride of aluminium is added sufficient metallic zinc (or tin or tin and zinc) as it will dissolve. While dissolving the solution should be kept boiling, the water evaporating being replaced. Instead of dissolving the metal chemically it may be dissolved as an anode. To the resulting solution is added from 0.2 per cent to 0.3 per cent of chloride of zinc (or of chloride of tin or of the chlorides of zinc and tin) and the boiling continued for about one-half hour. The solution may also contain an organic acid, as citric or tartaric acids. A small quantity of chloride, or sulphate, or nitrate of mercury may also be added. The deposit obtained from such a solution is said to be compact, smooth and durable.

Book Review

Laboratory Manual of Glass Blowing. By **Francis C. Frary, Ph.D.** Small 12mo., 57 pages, 75 cents. New York and London: McGraw-Hill Book Company, Inc.

A brief manual of instructions in the art of glass blowing that will be of value not only to beginners but also to those with some skill. The instructions are clear and concise and are well supplemented by illustrations.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIII. NEW YORK, MAY, 1915 No. 5

PUBLISHED MONTHLY BY THE
McGRAW PUBLISHING COMPANY, INC.
JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DeMOTT, Treasurer.
239 West 39th Street, New York.
TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Colo.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for May, 1915

EDITORIAL:
The Contributions of Chemistry to the Industries of the United States 269
Conditions in Mexico 270
The Distribution of Steel 270
The Government's Alaskan Railroad 271
READERS' VIEWS AND COMMENTS:
Government Publicity Methods. By Walter O. Snelling.. 273
The Western Metallurgical Field 273
The Iron and Steel Market 275
The American Electrochemical Society in its External Relations. By F. Austin Lidbury 277
New Orleans Meeting of American Chemical Society 280
Abstracts of papers by A. D. Little, C. S. Ash, J. B. F. Herreshoff, E. T. Bedford, J. L. Rake, D. Wesson, G. S. Brown, W. D. Horne, F. W. Hobbs, H. W. Wallace, F. R. Hazard, W. H. Teas, J. A. Wesener and G. L. Teller, G. D. Thevenot, R. I. Bentley, W. P. Mason, R. C. Schüpphaus, A. A. Houghton, F. L. Moore and Bernhard C. Hesse.
The Reburning of Lime from Alkali Waste and Other Forms of Precipitated Carbonate of Lime. By Richard K. Meade 289
Carbonate Control in Ferric-Chloride Leaching of Sulphide Copper Ores. By F. N. Flynn and Roger H. Hatchett... 291
Notes on the Reverberatory Furnace. By Francis R. Pyne... 292
The Extraction of Carbolic Acid from Oils of the Distillation of Coal Tar. By William Mason 293
The Non-Ferrous Metal Market 294
A Case for Copper Hydrometallurgy. By George C. Westby 295
Industrial Motor Applications. By H. B. Barnes 297
Melting Points of Chemical Elements and Other Standard Temperatures 302
The Formation and Decomposition of Sulphates During Roasting. By Boyd Dudley, Jr. 303
Flotation in Gold Metallurgy. By W. B. Blyth 308
The Cyanamid Process. By Frank S. Washburn 309
Atlantic City Meeting of the American Electrochemical Society 314
Abstracts of papers by E. W. Weintraub, Boyd Dudley, Jr., O. L. Kowalke and D. S. Grenfell, W. S. Franklin, Wilder D. Bancroft, T. S. Fuller, M. deKay Thompson and Ernest C. Crocker, L. D. Ricketts, Utley Wedge, E. A. Cappelen Smith, George W. Van Arsdale, Raymond D. Bacon, Frederick J. Pope, J. Park Channing, R. C. Canby, Richard Lamb, Lawrence Addicks, G. W. Van Arsdale, John V. N. Dorr, Francis C. Frary and Harry C. Berman, W. E. Ruder, Leland L. Summers, F. S. Washburn, Herbert Ives, William C. Moore, R. E. Harrington, Edgar F. Smith, Oliver P. Watts, Frank C. Mathers and Asa McKinney, Herbert T. Kalmus, C. H. Harper and W. L. Lavell.
Metallurgical and Chemical Engineering in Great Britain.... 329
Synopsis of Recent Chemical and Metallurgical Literature... 330
Powdered Coal Plant at Anaconda 333
Poidmeter Test 336
Electric Steel Refining 336
An Improved Diaphragm Material—Electro-Filtros. By C. J. Thatcher 336
New Cupels 338
What the Panama-Pacific International Exposition Means to the Metallurgical and Chemical Engineer 339
Personal 340
Digest of Electrochemical U. S. Patents 341
Book Reviews 342

The Contributions of Chemistry to the Industries of the United States

The most prominent feature of the celebration of the fiftieth convention of the American Chemical Society, held in New Orleans last month, was the elaborate symposium of papers on contributions of the chemist to the American industries before the Industrial Section. Introduced by a brilliant address by Dr. Arthur D. Little on the industrial resources and opportunities of the South and concluded by an able summary by Dr. Bernhard C. Hesse of the record of achievements of American chemistry, the symposium proper comprised nineteen papers on the decisive influence which chemistry and the chemist have had on the development of the wine industry, the copper industry, the corn products industry, the asphalt industry, the cement industry, the sugar industry, the incandescent gas mantle industry, the textile industry, the fertilizer industry, the soda industry, the leather industry, the flour industry, the brewing industry, the preserved-foods industry, the potable water industry, the celluloid and nitrocellulose industry, the glass industry, and the pulp and paper industry.

This record of chemical achievements is certainly impressive. It is the more impressive as in a way these nineteen papers scratched only the surface. For instance, of all the contributions of chemistry to metallurgy, only those relating to copper metallurgy were dealt with. Yet it is perfectly true to say that the functions of the chemist are now looming large besides those of the mechanical and mining engineer in the modern metallurgy of any and every metal, not the least in the biggest of all metallurgical industries, that of iron and steel. And the electrometallurgical achievements of the last decades would have been simply impossible without the chemist; the aluminium industry would simply not exist had it not been for the work of the chemist.

In spite of its shortcomings this symposium was very successful. It was timely. With the popular outcry in our ears that lack of "spunk" has prevented American chemists from creating a complete dyestuff industry, it was necessary to impress on the public the fundamental fact that the sphere of influence of the chemist reaches far beyond the boundaries of the chemical industries. Indeed, the influence of chemistry reaches into every industry, just as does the influence of the mechanical engineer. But while the mechanical engineer is usually called in at the beginning of an industrial development, the function of the chemist starts generally much later, when refinements, recovery of by-products and the avoidance of waste become important. His work is not less important than that of

the mechanical engineer, but it is not equally visible, it does not impress itself directly on the public.

Of course, as all industries depend upon materials and very often upon materials which are not provided by nature but must be specially made and fitted to the case, and as this is the more true the further an industry advances, all industries depend upon chemistry. This is perfectly obvious, but it does not state the whole case. Chemistry is more than a mere collection of facts on elements, compounds, and materials. It is a habit of thought, a viewpoint. When the Perkin medal was recently presented to Dr. Edward Weston, Dr. Baekeland in his address (published in our March issue) showed in a very clever way how the "chemical viewpoint" which Weston had acquired in his youth by his electrochemical work, had helped him later in his electrical engineering work. What is true of an individual evolution is more broadly true of broad industrial developments. The solution of an industrial problem depends, first of all, upon the correct formulation of the problem. And the correct formulation of the problem depends on the viewpoint—a narrow viewpoint, based on man-made classifications and conceptions is fatal. Every new and true viewpoint that can be brought to bear upon a problem is of inestimable value. For this reason alone the chemist cannot be ignored by any industry whatsoever. What he has done in the past for the development of the American industries entitles him to hold up his head with pride. This was the keynote of the New Orleans symposium.

Nor does the American chemist need to be ashamed of the development of the American chemical industries proper. While this country has no complete dyestuff industry, it has an electrochemical industry that is the child of the American soil and is not equalled anywhere in the world. As Mr. Lidbury put it in his brilliant presidential address before the American Electrochemical Society last week, "in spite of its youth, the absence of the electrochemical industry from among the industries of the country would cause such industrial disturbance that the plaint of the wearer of many colors, always imminent but not up to the present moment audible, would pass unnoticed."

Conditions in Mexico

Villa's recent proclamation of new laws governing mining in Mexico has complicated an already intolerable situation and has stirred the representatives of foreign mining companies in Chihuahua to earnest protest. Although life and liberty there have long been in jeopardy and "57 varieties" of paper money have created financial chaos, no concerted protest has been made against high-handed methods of government until the present decree threatened the confiscation of mining property. The protest has already borne fruit; our State Department announces that exemption from the terms of the decree can be secured on proper representations to the Minister of Fomento at Chihuahua.

The reformed Article 51 of the mining law provides, in brief, forfeiture of mining property for (1) nonpayment of taxes; (2) voluntary suspension of work; (3) abandonment of work; (4) insufficient exploitation, and (5) failure to "maintain in activity at least one working exploitation within each five pertenencias (10 acres), or fraction thereof." The decree announces that these restrictions are necessary in order to insure mining activity so "that the exchequer should lose none of its incomes which are indispensable for the fulfillment of its obligations." The latter evidently rest heavily on the government!

Mexican ideas of justice are beyond comprehension. Having created conditions that forced prudent people to leave the country and abandon their property until such time as they could return to it in safety, the Mexican authorities now decree that such property shall be forfeited to the country unless it is made productive and that at once. Payment of taxes, often in duplicate to successive and opposing chieftains, is not sufficient to hold title in the absence of actual operation. The fact that supplies are scarce or even unprocurable; that operations could not be conducted except at a loss, and that the terms of the decree are ridiculous from an engineering standpoint—none of these things move the Mexican chief.

Villa has been a popular leader, as leaders go in Mexico. His cause has had moral support from such engineers as have been disposed to take a partisan stand in the interests of peace in Mexico. Hitherto he has been considerate and tolerant, and has won a substantial following. Recent press dispatches indicate military reverses to his arms, but such disasters will not be as potent in effecting his downfall as will the blind and foolish enforcement of his mining decree.

The Distribution of Steel

A superstition has lately arisen that a very large proportion of the steel now being produced in the United States is passing into "war material," and it may be well not only to suggest that such is not the case, but since we have brought the subject up, to point out that the distribution of steel, into various consuming industries, is very different indeed from the distribution that obtained only a few years ago.

We must define our measuring rod first. It is commonly reported that the steel industry has lately been operating at about 70 per cent of its capacity. It is probably not far wrong to assume that the actual production in 1913, the record year, represented about 85 per cent of the present productive capacity. If so, production is now at the rate of about 25,000,000 gross tons annually of steel ingots and 19,000,000 gross tons of rolled steel, weighed in the form in which the steel leaves the hot rolls and shears.

Since the early weeks of the war there have been constant rumors of very large orders being placed for steel for war purposes, but the official statistics of exports as they have appeared month by month have successively proved the incorrectness of the major portion of the reports that had been circulated. In recent weeks the reports have become more insistent, but in the light of previous experiences we are justified in discounting them very heavily. The latest official returns, made public

within the past ten days, are for February and show total exports of all iron and steel returned by weight of 144,366 gross tons, this comparing with 139,791 tons in January. While this shows an increase, the best month since the war started lies as far back as October, with 147,293 tons, so that the February statistics disclose no definitely increasing tendency in the total iron and steel exports. Making allowance for the scrap, pig iron and cast iron included in the February total there was left material representing about 125,000 tons of rolled steel, representing 7.9 per cent of the current production. If the exports had since increased by one-half, which is quite improbable, they would represent only 12 per cent of the current production. In any event, a very considerable part of the material exported is not for war purposes. Nor can any very large tonnage of war steel be concealed in other listings than as tonnage exports, as unclassified manufactures of steel show decreases instead of increases since the war started. Even with a large percentage increase in the exports of lathes and other machine tools, lately required for the manufacture of arms and projectiles, the exports of this class of machinery have increased only by something like $1,000,000 per month in value, so that the weight of iron and steel involved can amount to but a very few thousands of tons a month. Exports of motor trucks appear large simply because there was very little such business before the war, an average of less than 100 trucks per month, while the exports in February were 1002 trucks and, in the eight months ending February, 4974 trucks. There was, however, a large decrease in exports of pleasure cars. The exports at present evidently represent less than 5000 tons of iron and steel per month, and not much more than before the war.

There is reason to conclude, therefore, that the total exports of the United States do not involve more than 15 per cent, possibly no more than 10 per cent, of the steel now being produced.

The steel that remains at home is being distributed quite differently than a few years ago. In 1906 the production of steel rails for home consumption was 3,650,000 tons, or 21 per cent of the total finished steel output. At the present time rails for domestic consumption represent considerably less than 10 per cent of the current steel output. In 1906 structural shapes represented more than 12 per cent of the total steel output. The reports of fabricated steel contracts let show an average of 51,000 net tons per month in December, January and February, and 110,000 net tons in March. A considerable proportion of this tonnage is plates, while there is very little consumption of structural shapes in car building and miscellaneous work, and it may be estimated that about one-half as large a percentage of the current steel output is passing into structural shapes than was the case in 1906. In 1906 nearly 7000 locomotives and 240,000 freight cars were built, involving about 4,000,000 gross tons of steel, or 23 per cent of the steel output. To-day it is certain that less than 5 per cent of the current steel output is passing into cars and locomotives for domestic use.

In practically all the other lines of steel consumption the percentages have greatly increased since 1906. The motor-car industry has risen from practically nothing, and in the past few months, the height of the manufacturing season, has probably been taking from 3 to 5 per cent of the current steel output, apart from its consumption of castings and forgings. The tin-plate industry is consuming more than 6 per cent of the finished steel output at present, against 3.3 per cent in 1906. The sheet industry accounted for 6.2 per cent of the steel output in 1906, and now involves a slightly larger proportion. In wire, wrought pipe and merchant bars the proportions have very greatly increased.

It is possible to generalize from this comparison and to observe that steel is passing much more into the articles of common everyday consumption and much less, proportionately, into large structures, such as bridges, buildings, etc., and railroad use. By no means does it follow, of course, that the altered distribution is to be permanent. Rather it may be suggested that since it has been extremely difficult in the past nine months or more to effect any new financing, the time may come when large undertakings will be resumed in numbers, with, of course, no decrease but rather an increase in the common everyday consumption of steel. If so, there will be a total demand for steel that the industry as now constituted cannot possibly supply. It is reported to be operating at 70 per cent of capacity at present and it is asserted that sufficient labor could not be found to operate it at 100 per cent. The situation is fraught with interesting possibilities for the next few months.

The Government's Alaskan Railroad

Based on the acquisition of the existing Alaska Northern Railroad as a first link, the Government has undertaken the construction of a railroad from Seward to Fairbanks, Alaska, a distance of 471 miles. A branch line of 38 miles is to be built into the Matanuska coal fields. The price to be paid for the Alaska Northern is $1,150,000, a rate per mile much less than half the estimated cost for constructing the balance of the road. The commission's estimate for building 438 miles of railroad is $26,800,000.

The official route, announced by President Wilson on April 10, is from Seward, on Resurrection Bay, along the Kenai Peninsula to Turnagain Arm of Cook Inlet, thence through the Susitna Valley, across Broad Pass and down the Nenana River to Fairbanks on the Tanana River. The work is to be under the direction of the Alaska Engineering Commission, consisting of William C. Edes, chairman; Lieutenant Frederic Mears and Thomas Riggs, Jr. It is expected that about 40 miles of railroad can be constructed this year.

The adopted route will open and exploit a territory not now served by a railroad, and will assist materially in the development of two important coal fields: the Matanuska and the Nenana. A supply of fuel from these districts will be of the greatest importance to the industrial development of Alaska. Fairbanks, the inland terminus of the road, is the center of an important gold mining industry.

Readers' Views and Comments

Government Publicity Methods

To the Editor of Metallurgical & Chemical Engineering.

Sir:—Criticism of Dr. Rittman continues to fill a considerable portion of the oil journals and shows little signs of abating after more than six weeks from the date on which his discoveries were announced to the public. Since much of this criticism is based on an incomplete knowledge of the real facts in the case and is decidedly unjust to Dr. Rittman, I feel that it is only proper that I should make known certain conditions which up to now have apparently not been given proper consideration.

Dr. Rittman and myself are rivals in the development of oil-converting processes, but I do not want any advantage in this contest to come to me because of wholly unmerited personal attacks on Rittman, or criticism of him which is not only unfair, but almost wholly misdirected. In the May and June (1914) numbers of the "Journal of Industrial and Engineering Chemistry" there will be found a most scholarly and comprehensive article by M. C. Whitaker and W. F. Rittman, in which the basis of Dr. Rittman's work in oil cracking is discussed in a thoroughly scientific spirit. This article should be sufficient to establish the scientific standing of Dr. Rittman, and forces anyone who gives it careful attention to admire the patient work, and the brilliant results which were obtained. That Whitaker and Rittman have done most important and valuable work in the cracking of oils will not be doubted by anyone who takes the time to read the results obtained in these important papers.

That there have been some very unfortunate and probably highly improper publicity methods used in bringing the Rittman work before the public is undoubted, and my purpose in this statement is to place the blame where it belongs. Up to now it has been laid on both Rittman and on the newspapers, but I believe I can show that in neither case is the criticism justified.

Although Congress has repeatedly insisted that no part of the funds allotted to the government departments are to be used in press agent work, it is a matter of common knowledge that several of the government departments systematically violate these provisions. The Bureau of Mines, in particular, maintains a very active publicity department, the work of which can be well seen in the recent Rittman announcements, including the numerous personal interest stories of Rittman's muscular development, his football prowess, his helpful wife, etc., etc., ad nauseam. No person who knows anything of the scientific work of Rittman can believe for a moment that he has been a willing party to publicity efforts of such a nature.

About a year ago the newspapers of this country were filled with radium press notices. A bill was before Congress carrying an appropriation of $450,000 for radium research by the Bureau of Mines, and apparently the bureau press agents worked overtime in their efforts to convince the people of this country that radium had almost miracle-working properties. Day after day the newspapers carried press notices of a misleading, if not of a wholly false character, and no efforts seem to have been spared in this compaign of publicity. In the Associated Sunday Magazines, which form the supplement of many Sunday newspapers, on Feb. 22, 1914, there was published an article by Franklin K. Lane, and using his official title as Secretary of the Interior. The opening sentence of this article is as follows:

> "When we reflect that the production of every additional half-gram of radium means the saving of a human life a day from the ravages of cancer, no question can remain of our obligation to conserve and make available for use all the radium resources of this country."

At the time this article was written it is not at all certain that a single human life had been saved by radium. As a matter of fact, eminent medical authorities insisted at that time, and still insist, that no case of deep-seated cancer has ever been cured by radium, and that its exploitation as a curative agent for cancer has been due largely, if not wholly, to the efforts of parties who expected to financially profit by it.

Personally I believe that the numerous misstatements which went through all the American newspapers a year ago were part of a systematic and organized campaign for the purpose of insuring the passage of the Bureau of Mines appropriation bill of $450,000 for radium research. There are strong reasons for believing that the officials of the Bureau of Mines knew at the time that radium had no such curative powers as were being claimed for it.

The many points of similarity between the radium publicity methods and the methods recently used to introduce the Rittman discoveries to the public, will probably be noted by anyone who cares to look into the matter. As a matter of fact I have personally seen some of the press notice sheets which were handed out to the newspapers of this country in regard to the Rittman publicity. The newspapers published these sheets in practically the identical form in which they came to them.

I do not feel that the present is a proper time to enter into any detailed explanation as to just what motives are behind the work of the Bureau of Mines in exploiting the present cracking process. I will only state my belief that beneath it all there will be found certain conditions which go back somewhat over five years and which are not in any way creditable to certain officials of the Bureau of Mines, who are concerned in the matter. I believe it will be later shown that many of the details of my experiments in bringing about equilibrium conditions in hydrocarbons, with the production of large yields of gasoline, have been known to certain officials of the Bureau of Mines for a number of years past, and that Dr. Rittman was only employed by the bureau after the publication of his brilliant work at Columbia University had proved him to be a man particularly able to serve the interests that certain officials of the Bureau of Mines had in view.

There are, however, some points in regard to this recent work of the Bureau of Mines which are probably deserving of more or less immediate attention. It is known that in the development of the Rittman process, as in the development of the radium plans of a year ago, the bureau is working in coöperation with certain private interests and under agreements which are kept carefully secret.

We know to-day that a private company, the Aetna Explosive Company, has agreed to expend $200,000 in the development of the benzol and toluol end of the Rittman process, and that at present development work on a very large scale is going on in Pittsburgh. We also know that until this work is completed no further information is to be given out in regard to the process.

It is most interesting to note that it is an explosives

concern which has advanced the money to develop this process. It is also significant that the Rittman process is stated to be capable of producing a very good yield of toluene, a material which is very much in demand at the present moment, because of the war abroad, nitrotoluene being the principal explosive used in shell charges. Since the war commenced my laboratory has been receiving repeated requests for toluene and nitrotoluene, and I personally know that inquiries for toluene and nitrotoluene in very large amounts have been made in this country in the last few months.

At this psychological moment, when any process for making toluene economically can be made to yield profits of several million dollars within the course of a comparatively few weeks, an explosives concern friendly to the Bureau of Mines makes an agreement with the bureau by which it spends $200,000 in developing the Rittman process for the production of toluene from petroleum. During the life of this secret agreement it is understood that the Aetna Company is to have the exclusive use of the Rittman inventions and of all the products which can be obtained by their operation.

It is quite evident that to carry out the successful development of any scheme for using a government process and government chemists at the present time in the production of toluol, it is most desirable that the government officials should have no knowledge as to the use to which the toluol is to be put, or its final destination. With the painstaking thoroughness which characterizes much of the work of the Bureau of Mines apparently even this detail has been carefully attended to, and it is with great relief that we read in a letter written by Van H. Manning, of the Bureau of Mines, to the *Oil, Paint and Drug Reporter* under date of March 22, 1915, as follows:

"The products derived are, of course, to be the property of the Aetna Company, and this Bureau is not aware what arrangements have been made by such company for the use or disposition of the products."

I think it is very fortunate indeed that Mr. Manning has thus been kept in entire ignorance of the purposes for which the Aetna Company desires the toluene. He is probably firmly of the belief that this toluene is to be used in making whitewash, or soap, or alarm clocks. Anything, in fact, except explosives. How very fortunate it is that in all the negotiations which have been carried out between the Aetna Company and the Bureau of Mines, neither Mr. Manning nor any of his associates should have evinced any interest as to the reasons which actuate the Aetna Company to expend this large amount of money in experimental work in return for the exclusive right to use the process during the time that the present high prices for toluol exist. Later, when all the war orders have been filled, and toluene sinks to its normal level, below the price at which toluene can be economically produced by the Rittman process in competition with coal tar distillates, then, no doubt, the Rittman process will be thrown open to the general use of the American people. But for anyone to believe that it will thus be thrown open to the use of the general public untill all the "cream" has been cautiously removed, or until the process is found to be economically inoperative, for anyone to believe that, either betrays entirely unjustified credulity, or a faith in human nature which is not in line with the past actions of the very clever politicians of the Bureau of Mines.

I do not want these statements of mine to be in any way construed as a wholesale condemnation of the working of the government departments. Some of the government departments follow as high a standard of ethics as exist anywhere. I believe the patent office, in particular, before which the Rittman process must have its final review, is wholly incorruptible. Neither do I believe that Dr. Rittman is in any way responsible for, or a knowing party to, anything improper in the plans of the Bureau of Mines. Men of the highest scientific standing and ability have apparently in the past been used as tools by the Bureau of Mines in affairs which these men would have been the first to denounce had they known their true inwardness.

I believe the time has come to turn the searchlight of publicity upon the government officials and the government departments who are concerned in such matters as I have here referred to.

Pittsburgh, Pa. WALTER O. SNELLING.

The Western Metallurgical Field

Concentration of Carnotite Ores

The concentration of low-grade carnotite ores, which has been talked about and experimented on for so long, is now an accomplished fact, being in operation in two plants in Southwestern Colorado. The Standard Chemical Co. and the National Radium Institute have perfected methods of concentration and each has a plant that is in continuous and successful operation, that of the latter under the technical direction of the Bureau of Mines.

The necessity of concentrating the low-grade carnotite ores of Colorado has long been recognized on account of the isolation of the region in which they are found, the economic necessity of treating them at some point distance from the place of their occurrence and the high cost of transportation. In the first careful investigation made on these ores and their treatment by Dr. Herman Fleck and Prof. W. G. Haldane of the Colorado School of Mines the desirability of concentration was recognized and the principles of a process were disclosed. In their report, which was embodied in that of the Commissioner of Mines for Colorado, 1905-6, they state:

"Perhaps no method of ore dressing could be succesfully applied. The extremely fine state of division of the mineral precludes this. Magnetic methods have been experimented with, but to no effect. A microscopic observation made on the ore showed, in a sample of ore from hydraulic, carrying about 4.5 per cent. uranium oxide, that the somewhat worn but yet distinct quartz crystals composing the grains were cemented by carbonate of lime, and that the carnotite adheres to the face of the crystals after rubbing the grains free from most of the carnotite dust. This suggested a method of preliminary sliming and subsequent attrition, whereby the values in the form of slimes might be easily filter pressed or settled. Machinery for the purpose of subjecting the sand grains to attrition could readily be devised."

Subsequently, other engineers experimented along this line, and the present processes in operation are based on these principles. In the Bureau of Mines *Bulletin* 70, Messrs. Moore and Kithil discuss both wet and dry methods of concentration, and give experimental results. The definite establishment of concentrating mills in the carnotite-producing region of Colorado is an event of economic importance in the uranium, vanadium and radium industries.

Alaska Gastineau Mill

When the first unit of the new mill of the Alaska Gold Mines Co. was put in operation on February 18, 1915, the promoters of a tremendous enterprise in gold mining and milling began to see the fruition of several years of labor. That the operation of the first unit started so favorably and demonstrated a capacity beyond the calculations of the designers, is a tribute to the

conservative care with which the work has been done. As first planned, the mill was to have a total capacity of 6000 tons in 24 hours, each of the four units having a capacity of 1500 tons. Mr. Jackling has stated that it now appears that the capacity will be 2500 tons per unit, or a total of 10,000 tons per day, and that the recovery is fully up to his expectations and will check with the experimental results. The other sections of the mill will be in operation at intervals of from 40 to 60 days, and in the meantime the mine will be sufficiently opened to provide the tonnage. The ore thus far treated, coming from six widely separated points in the mine, is reported to average nearly $2 per ton.

Interest in this mill centers in the radical departure from the customary methods of milling gold ores. In general, the method adopted follows the process which is in use in concentrating low-grade prophyry copper ores in Utah and Arizona. The ore passes over grizzlies, and the oversize is broken in jaw crushers. The grizzly undersize and the product of the jaw crushers is further crushed to 2-in. size in gyratories. This is followed by roll crushing in Garfield rolls of 72 in. and 54 in., with intermediate screening. Impact screens of 10-mesh finish the dry-crushing and screening process.

Concentration begins on Garfield roughing tables and is continued on Wilfley tables. The discard is classified, the coarse portion being ground in tube-mills and the concentrating process repeated. Concentrates of different grade are the products, and these are shipped to reduction works. Some high-class concentrate is reduced to base bullion at the mill.

Chloridizing at Park City, Utah

Resumption of operations at the Park City Mills is scheduled for May 1. This plant started operations last Fall, but a short run was unsatisfactory to the operators, and it was decided to make a change in the roasting furnace in which the chloridizing operation is performed. In view of the success of the Holt-Dern roaster at the mill of the Mines Operating Co., at Park City, it was decided to install a furnace of that type. This machine has been completed and is practically installed. The ore to be treated will come from the American Flag mine. Its principal value is in silver, with some gold, lead and copper, being a typical "complex" ore. The mixture for the roast contains ore, salt and coal, and the product is subjected to leaching with a salt solution. The metals are recovered by precipitation. Details of the process as carried out at the mill of the Mines Operating Co. have been given in this journal, July, 1914, page 431. An article on a similar process at Silver City, Utah, appeared in our issue for December, 1914, page 757.

Zinc Smelting at Pittsburg, Kansas

Information from Joplin is to the effect that the Pittsburg Zinc Co. has resumed operations at its smelter, which has been idle for several years. The plant has 1600 retorts, and coal is used for fuel. J. G. Starr is in charge of operations, and associated with him are members of the Lanyon family who have long been connected with the zinc industry.

Federal Investigation of Smelters

Too late for report in our last issue we learned that Federal authorities are investigating the possibility of an unlawful combination of smelters handling Missouri lead ores. It is alleged that a combination exists to fix prices and control the market for lead ores. The Department of Commerce made a perliminary probe and was followed later by the Department of Justice. The State Attorney General also has indicated his willingness to join in the search. No announcement has been made as to the results of the investigation.

Company Reports

Nevada-Douglas Consolidated Copper Co. has been reorganized, the new company including the former Nevada-Douglas Copper Co. and Moore Mining Co. The company is erecting a mill for the treatment of copper ore by the Rankin nitric acid leaching process. The plant is not complete, work being suspended about the time the European war broke out. An assessment has been levied to provide funds to complete the plant and put it in operation.

The American Smelting & Refining Company's sixteenth annual report, covering the calendar year 1914, shows total earnings of $10,811,915; depreciation, $1,540,350; loss incidental to European and Mexican wars, $240,000; net earnings applicable to dividends, $9,031,565; preferred stock dividends, $6,017,450; common stock dividends, $2,000,000; surplus, $1,014,115.

The conditions of affairs in Mexico has operated to decrease the company's earnings. In August it appeared as though operations might be resumed at the Mexican smelters, but such was not the case. Conditions there continue to be a source of worry to the directors.

The total volume of the year's business was $200,925,625, of which 4.49 per cent, or $9,031,565, was available for dividends. The value of the four principal products was: Gold, $52,515,548; silver, $42,690,226; lead, $24,551,632; copper, $71,712,527. The company employs 12,179 men (excluding Mexico), and paid in wages $10,212,591.

Attention is directed to the diversity of the company's interests and operations. It is now refining and marketing gold, silver, lead, copper, zinc, nickel, platinum, arsenic, bismuth, cadmium, tellurium, selenium and palladium. It is also engaged in the manufacture of sulphuric acid and coke.

In welfare work the company has been active. The 3-shift, or 8-hour system has been adopted wherever practicable, less than 6 per cent of the labor working more than 8 hours. Wages have remained practically the same under the 8-hour system as when longer hours prevailed. Conservation of health of operatives and provisions for their safety have received attention. Life insurance has been taken out by the company in favor of the wife or family of the operatives, in the sum of $500 for unmarried men and $1000 for married employes. The pension fund now amounts to $520,238. During 1914 pensions were granted to 63 applicants, the average age of whom was 62 years.

The United States Smelting, Refining & Mining Co. shows in its ninth annual report, covering the calendar year 1914 earnings of all companies, $2,932,519; depreciation, $666,877; profit, $2,265,642; dividends, $2,228,891; undistributed surplus, including surplus from previous year, $4,515,591.

Metals produced in 1914: Copper, 17,946,659 lb.; lead, 64,443,260 lb.; silver, 9,936,237 oz.; gold, 124,719 oz. The percentage in value of each metal was: Copper, 18.9 per cent; lead, 18.9; silver, 42.1; gold, 20.1.

The company has experienced the usual difficulties incident to the wars in Mexico and Europe. In April the company's American staff was obliged to leave Pachuca, Mexico. The Mexican staff remained on the ground and continued operations on a small scale. Expenses have been met, but no profit was made. No property damage has been done and the employes have not been molested.

The exploration department had presented for its consideration 639 properties. Of these 538 were rejected on an office examination of reports and data. A preliminary examination was made of 82, and 19 were accorded a complete examination. No purchases are reported. The company has been investigating the possibilities of oil fields in California, Wyoming and Mexico.

The American Zinc, Lead & Smelting Co. reports a total profit in 1914 amounting to $186,157, from which a net profit was carried to surplus account of $65,692. While conditions in the zinc industry were not satisfactory, nevertheless they were better than in 1913, when the company incurred an operating loss of $91,656. The European war, however, has made the United States the center of the spelter industry, and as long as the war lasts the price of spelter will be at a high figure. The company's smelters have a capacity of 110,000 tons of concentrates per annum and should produce 50,000 tons of spelter, about 11 per cent of the total output of the United States.

The mill at the Tennessee property has been increased in capacity from 1000 tons a day to about 1600 tons. Sufficient ore is in sight to supply 1800 tons a day for more than ten years. Only a single mill was operated in Missouri. The Wisconsin properties are producing at a much greater rate than ever before. The Hillsboro smelter has been in successful operation. The Dearing smelter was closed in 1914, and the Dearing plant operates at only 20 per cent capacity. An arrangement has been made, however, to treat a part of the Butte & Superior concentrates, and both the Dearing and Caney plants are ready to operate at 75 per cent capacity.

The Tennessee Copper Co. in its annual report for 1914 gives ore production as 468,668 tons, and estimated ore reserves as 4,010,661 tons. Material smelted during the year, in tons, was as follows: Tennessee copper ore, 437,340; converter slag, 17,909; blast furnace slag, 21,664; sinter, 42,909; limestone, 20,258; matte, 83,182; total, 724,822; coke, 38,726. Copper production was 12,871,113 pounds, at an operating cost of $0.1184 per pound. The average price received for copper delivered during 1914 was $0.13706 per lb. The production of 60° Beaume acid was 210,163 tons, an increase over that of 1913, due chiefly to improved smelting conditions. Net sales of all products amounted to $3,307,365; gross earnings, $981,900; net earnings, $805,455; dividends, $600,000; reserve for depreciation, $100,000; surplus for the year, $50,767; total surplus, $1,908,207.

The Nipissing Mines Company's report for 1914 states that the year was one of the most profitable in the history of the company. Silver production amounted to 4,689,333 oz.; gross value, $2,516,064. Net receipts were $1,587,621. Production cost was 19.8 cents per ounce of silver, being 4.29 cents per ounce less than in 1913. Average price at which silver was sold, 55.36 cents per ounce; in 1913 it was 60.26 cents, the decline being due largely to the war. Ore reserves amount to more than 10,000,000 oz. silver, an increase of more than 500,000 oz. over 1913. Surplus amounts to $1,602,776, an increase of $343,715. Dividends amounted to 20 per cent or $1,200,000. There was no change in treatment at the high-grade mill, which handled 929 tons of Nipissing ore of average value of 2439 oz. silver and 965 tons of custom ore of average grade of 2421 oz. silver per ton. The market for cobalt-nickel residue was good for the first half year, but was cut off by the war. The net income from 1060 tons of residue was $42,344. The low-grade mill treated 79,009 tons of ore of average grade of 30.82 oz. silver per ton. The actual recovery by clean-up was 89.64 per cent. Research work on the grinding operations showed that while practically all the rock in the final tube-mill discharge was finer than 200-mesh. metallic silver was flattened and would not pass. Two Callow screens have therefore been placed in the tube-mill circuits and are recovering from 20 per cent to 25 per cent of the silver in the ore. The dirty metallics are cleaned on a Wilfley table. Notwithstanding the increased cost of cyanide and other supplies, the total cost of treatment in the low-grade mill was $0.14 per ton less than in 1913, amounting to $3.989, distributed as follows:

	Cost per ton
Crushing at mine	$0.125
Aerial tramway	.065
Surface tramway	.069
Picking plant	.204
Crushing and conveying	.048
Battery	.275
Tube mills and classifiers	.575
Desulphurizing and slime collecting	.304
Intermediate filtering	.111
Cyanide treatment	1.076
Cyanide filter	.138
Clarifying and precipitation	.288
Refining	.111
Heating	.118
Water supply	.036
Construction	.334
Residue dam	.059
Consulting	.050
	$3.989

The Iron and Steel Market

Buying of steel products suffered an abrupt reduction at the beginning of April by reason of the termination of a number of contracts written at lower prices than obtained in the corresponding contracts for the second quarter. In other lines the bookings have been undiminished. As the mills were fairly well provided with specifications operations have been continued through April at an average rate of about 70 per cent of capacity.

In bars, plates and shapes the placing of strictly new orders was somewhat discouraged by the advance of the mills to a basis of 1.20c. This was in accordance with a program announced by various large mills early in February, that their price would be 1.10c. for specifications to be filed during February, 1.15c. for March and 1.20c. for second quarter. Serious doubts were entertained whether the 1.20c. quotation would really become effective. The price was fairly well maintained in April, but the market was subjected to no serious tests by large inquiries.

The first half of April developing no new encouraging influences, sentiment in some quarters began to become less hopeful, but later in the month encouraging developments began to appear again. On April 20 the Lake Superior ore market opened, and the early sales were larger than had been expected. War orders were reported in greater numbers. The Pennsylvania railroad system announced a budget of $32,000,000 for the year, to cover new rolling stock, rails and track work in general, and while it was explained that this represented merely the limit of the possible expenditures the news was regarded as favorable and hopes were entertained that other railroads would be moved to enter the market also. The Youngstown Sheet & Tube Company, an important independent steel interest, made a large purchase of pig iron, although it was operating all of its four furnaces, this being the first large purchase of steel-making pig iron in the Pittsburgh district for months.

In the past few weeks the steel market has had two courses open to it. With no definite increase in consuming demand, and mills operating at only 70 per cent of capacity, it would be difficult if not impossible for the advances recently made in certain prices to be maintained, buyers would endeavor to restrict their purchases, and operations would probably eventually decline, though not to the exceptionally low rate of last November and December.

On the other hand, with a slight further increase in actual consumption mill operations would increase beyond 70 per cent, approaching rapidly the point at which deliveries of some products would fall behind, an occurrence that is always the signal for forward buying and for replenishment of stocks by jobbers and manufacturing consumers. The process is a familiar one in

the steel market, a fresh demand arising almost over night when the condition changes from one of buyers being able to obtain almost instant delivery against any specifications filed to one in which the buyer must wait a few weeks for complete delivery against a miscellaneous specification. Once the steel industry reaches such a condition, it is certain to operate at practically its fullest capacity for months. The gap to be bridged was not between 70 per cent and 100 per cent, but between 70 per cent and 80, 85 or 90 per cent, for after so long a period of restricted operations and with alien emigration in excess for a twelvemonth past it has been the general opinion that the steel industry could not open short notice operations at 100 per cent of its physical capacity.

The developments of the latter part of April have disclosed a decided balance of probability that the pendulum will swing in the direction of larger demand, resulting in forward buying, advancing prices and even, possibly, an actual "runway market."

Iron Ore

Since the Lake Superior iron ore interests abandoned their price agreement several years ago each season has been "opened" by one interest or another effecting sales, others immediately adopting the price level thus indicated. This year the first sales appear to have been made by W. P. Snyder & Company and selling at once became general. As had been expected for months, prices were the same as ruled in 1914 and 1912, 1913 prices having been 60c. to 65c. higher, as follows: Old range Bessemer, $3.75; old range non-Bessemer, $3; Mesabi Bessemer, $3.50; Mesabi non-Bessemer, $2.85 per ton 2240 lb. on Lake Erie docks, for 55 per cent ore in the case of Bessemer and 5150 per cent ore in the case of non-Bessemer. The prices are as low as have obtained at any time since 1904, and are really very low considering the royalties ruling and the cost of stripping large quantities of over-burden in the case of many operations. The net price of an ore is determined on a unit basis, 60 cents, an arbitrary freight adjustment, being added to the base price on dock, the total being divided by the number of units in the base ore. Thus the unit price on Mesabi non-Bessemer is approximately 6.7c. Between 50 and 53 per cent there is a straight adjustment, the unit price being increased above 53 per cent, while between 49 and 50 per cent the unit price is multiplied by one and one-half and between 48 and 49 per cent it is multiplied by two. Thus for 48 per cent ore—we are referring entirely to Mesabi non-Bessemer—the total deduction is five units or about 33c., making the net price on dock $2.52. The ore pays 60c. rail freight up to upper lake dock, 40c. vessel freight and 10c. dock charges, so that $1.42 would be realized at mine, a price which obviously affords profit only to mines operated under favorable conditions. Higher grade ores take care of themselves.

The opinion is expressed in ore circles that this season's movement down the lakes will be not less than 40,000,000 tons, against 32,000,000 tons in 1914 and 49,000,000 tons in 1913, the banner year.

Pig Iron

The spectacular movement in Buffalo pig iron, referred to a month ago, involved a total of more than 300,000 tons of iron, but on account of the low price at which the iron was sold, somewhat under $12 at furnace, the influence upon other pig-iron markets was depressing rather than stimulating and the pig-iron markets as a whole were decidedly quiet in April. There was, however, a fair movement in southern iron at $9.25, Birmingham, for prompt and at $9.50 for second half, while there was some fair buying of basic in the east, chiefly at cut prices. It may be found that the purchases of the Youngstown Sheet & Tube Company, made ten days before the end of the month, will prove of considerable sentimental importance. This interest operates four furnaces, but buys merchant iron when operating its steel departments at above 75 or 80 per cent of capacity. It purchased from W. P. Snyder & Company ,Ohio Iron & Steel Company and Andrews & Hitchcock Iron Company about 40,000 tons of basic, 17,500 tons of forge and 5000 tons of foundry iron for delivery to October 1 at practically current prices. This is the first large buying in the Pittsburgh district since December and the first buying by a steel works having furnaces of its own for many months. The market is quotable as follows: No. 2 foundry: delivered Philadelphia, $14 to $14.25; f.o.b. furnace, Buffalo, $12.50 to $13; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13; f.o.b. Birmingham, $9.25 to $9.50; at valley furnaces, 95c. higher delivered Pittsburgh: Bessemer, $13.60; basic, $12.50; No. 2 foundry, $12.75 to $13; gray forge, $12.50 to $12.75; malleable, $12.75.

Steel

Actual market transactions in billets and sheet bars have been light, consumers being well covered by contracts of various form. Specifications against these contracts have been steadily increasing. Prices are largely nominal at about $19 to $19.50 for billets and $19.50 to $20 for sheet bars, f.o.b. maker's mill, Youngstown, and about 50c. higher f.o.b. maker's mill, Pittsburgh. Rods are $25, Pittsburgh.

Finished Steel

Finished steel prices are fairly steady but in most lines the market has not been under much pressure on account of the existence of old contracts. Plates are being shaded, particularly in the Chicago district. Galvanized sheet quotations are largely nominal, some mills withdrawing entirely from the market, on account of the acute scarcity of spelter. Wire products have not developed a real market at the nominally advanced price and are quotable at the first of the two advances made early in the year.

Current quotations are as follows for ordinary deliveries and are f.o.b. Pittsburgh unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.20c.

Shapes, 1.20c.

Steel bars and bands, 1.20c., base; hoops, 1.25c. to 1.30c.

Iron bars, 1.15c., Pittsburgh; 1.15c., Philadelphia; 1.15c., Chicago.

Sheets, blue annealed, 10-gage, 1.35c.; black, 28-gage, 1.80c. to 1.85c.; galvanized, 28-gage, 3.40c. to 3.50c.; painted corrugated, 28-gage, 2c.; galvanized corrugated, 28-gage, 3.45c. to 3.55c.

Tin plate, $3.20 to $3.35 for 100-lb. cokes.

Steel pipe, 80 per cent off list.

Steel boiler tubes (less than carloads) 3½-in. to 4½-in., 75 per cent off list.

Tennessee Copper Company's production of sulphuric acid has increased from about 600 tons a day to an average of over 700 tons, the maximum daily production having been 820 tons. Based on 350 operating days in the year, the annual production is at the rate of 245,000 tons of acid. It is reported that the profits derived from this phase of the business are sufficient to pay the entire dividends on $5,000,000 of outstanding stock.

The American Electrochemical Society in Its External Relations

BY F. AUSTIN LIDBURY

Presidential Address Before the American Electrochemical Society.

Eight years ago, when the American Electrochemical Society was last the subject of a presidential address,[1] the society was faced by many serious problems relating to its growth and the continuance of its existence. Finance, the provision of papers, the attendance at meetings, questions regarding publications, matters involving even its independence were the subject of anxious thought and discussion. The successful growth, both extensive and intensive, of the society since that time must be a matter of extreme gratification to those whose devotion, energy, and wisdom at an anxious period of its existence guided the society in the direction which has led to its subsequent well-balanced development.

There comes a stage in the development of every organization such as ours at which the cultivation of the primary objects of its existence no longer demands all its efforts; it becomes free to devote itself to external activities, and to represent its membership and what it stands for in the larger affairs of life. Of course, it need not do so. A voter need not exercise his franchise; but we do not call him a good citizen for the omission. An innocuous reputation for respectability and learning can easily be maintained by any scientific body which carefully avoids contact with objectionable external realities; but it is the kind of reputation which attaches to that paragon of respectability who "passed by on the other side." In the last few years this society has shown gratifying indications that it takes no such narrow view of its duties or its interests, and I hope and expect that its activities in external matters will be progressively intensified and broadened.

Perhaps as good an illustration as any of the direction in which our duties and our interests lie can be found by considering our relations to current tendencies in government. The extension of legislative and bureaucratic activities which the last few years have seen has been too widely regarded by intelligent persons as a manifestation which would play itself out, on the principle that "if the fool would persist in his folly, he would become wise." Not only has this optimistic expectation not borne fruit, but reliance on it has to a large extent prevented the offer of information and guidance from those in a position to give it. There are signs that men of business are realizing their mistake in the matter, and it is time that the man of science and the engineer also realized theirs. What cannot be averted can at least be guided into intelligent channels.

The engineer—take the word in its widest sense—has been worrying about these matters for a long time, and occasionally he comes to the conclusion that what is needed is representation of himself in legislative bodies.[2] He had better remember that legislation is really lawyers' business. If the scientific and engineering professions would worry less about their "status" and pay more attention to making their opinions heard and their recommendations respected, they would cease to be bothered about the undue proportion of lawyers in legislative bodies.

For, on the whole, these lawyer-legislators are not so scornful of information and advice as we are inclined to believe. They try to get both whenever they can, and, when the practical business man, the technical man, the engineer held aloof, they went to the university professor and, when he was not available, to the charlatan and the agitator. They have shown their power of discrimination by preferring the professor; they instinctively felt that he knew more. If his guidance has led them into difficulties, it is because his truths are too often colored by his theoretical idiosyncrasies and not founded on a pragmatic basis. Until we have given the legislator all the assistance in our power, we are obviously not in any position to accuse him of spurning it. Nor does it particularly matter if he does, for the power of an intelligent minority, however small, is tremendous, and there is no man more sensitive to well-informed criticism of sufficient publicity than your legislator unless it be your bureaucrat.

I have attempted to indicate the extent to which the intelligence of government of a democracy is dependent upon the coöperation of its intelligent elements, and the extent of the responsibility in this regard of those professions which claim to embody the application of intelligence to industrial operations. A little self-examination will show that a well-defined portion of this responsibility rests upon the American Electrochemical Society.

We need have no false modesty about it, either in regard to what we represent or to what we are. We represent a branch of the chemical industry whose products are of such importance to the general industries of the country that, in spite of its youth, its absence at the present time from among the industries of the country would cause such industrial disturbance that the plaint of the wearer of many colors, always imminent but not up to the present moment audible, would pass unnoticed.

As a society, we are unusually representative. We embrace in the personality of our members and in the scope of our discussions the practical as well as the theoretical, the commercial as well as the technical; as a consequence our organization is capable of considering all phases of any question which comes within its scope. We have had a healthy growth, and our functions are normal; we do not suffer from overgrowth or uncorrelated parts, nor are we weakened by the overdevelopment of any particular activity. We have a representative constitution and its consequence, a responsible and responsive management. Finally, we are entirely independent, not only of outside influences, but also of any one class of internal opinion; the diverse nature of our membership guarantees us against the dangers of a narrow point of view.

Our duties are proportional to our possibilities. It will not be necessary for us to look around for subjects to which to devote our attention; many of these are clear; on some we have already made a beginning, some, still more important, we have not had the temerity to touch.

Perhaps there is no subject which will better illustrate our sins of omission (in common, I hasten to add, with many technical bodies equally interested in the matter) than our inaction in regard to legislation concerning water power. This is not the occasion on which to discuss the limitations which have been imposed upon the development of power at Niagara Falls; nor if it were, should I be able to add anything to the treatment of the subject by my predecessor in his presidential address at the last New York meeting.[3] I wish not to touch upon the controversial aspects of that question, but to point out that we have allowed the whole matter to go by default.

A combination of fortunate circumstances enabled our industry to grow in the last twenty years to the point where we are somewhat more than independent of foreign manufactures in electrochemical lines. What we do not suffer from we do not realize, and while almost

[1] Carl Hering, Trans. Amer. Electrochem. Soc., *11*, 17 (1907).
[2] See, for instance, E. W. Rice, Jr., on the "Status of the Engineer." Proc. A. I. E. E., *34*, 648 (1915).
[3] E. F. Roeber, Trans. Amer. Electrochem. Soc., *25*, 17 (1914).

everyone who reads the newspapers is able to growl at the comparatively small development of the organic chemical industry in this country, an appreciation of what the same condition in the electrochemical industries would mean is probably not general, even among our own members.

It was not alone the reliability of Niagara power or its comparative cheapness which made it a vital factor in the development of our industries; it was the combination of these with a favorable commercial location. It is quite possible that had the development of power at Niagara Falls been prohibited from the beginning instead of throttled in its infancy the growth of electrochemical industries in this country might so have fallen behind that in other lands as to make us as dependent in this respect as, for instance, we are for dyes. We owe it to ourselves, both individually and as a society, to take every opportunity of bringing about a widespread knowledge of this situation. The electrochemical industry is already paying the penalty in the way of increasing scarcity of power and rising prices in the Niagara district, for allowing matters to take their own course.

Turning to the broader aspects of power development, we find that curious ideas have received governmental sanction, and even action, without any attempt at correction by us. For instance, that water-powers could be best developed by preventing people from developing them—we actually approved of this idea in a solemn resolution[4]; that conservation and the interests of the people and particularly efficiency would be best subserved by preferably connecting water-power plants to the loads of precisely the lowest load factors known.[5] If ideas of this description are acted on through lack of careful and intelligent controversion, who is to blame for the result—the ignorant, or those who know and keep silent?

I turn to patent legislation. Here we have, chiefly through the tireless energy of one of our past presidents, a record of some activity. But much more ought to be done. The combined efforts of many societies such as ours have succeeded in averting some very serious consequences of ignorance, but the whole question calls for a great deal of constructive effort. I know of no matter which presents to us so many difficult aspects, and not the least difficult is the danger that in trying to do justice to the "inventor" we may fall into the error (so common among inventors themselves) of regarding him as "the whole thing" So many of us have to take a matter where the inventor leaves off and make it work that we know better; we have a peculiar knowledge of this subject, and it is our duty to see that it is not overlooked.

We are governed more and more by commissions, officers and bureaus. Insofar as the operations of these agencies are of a restrictive nature, untoward results, where they occur, are usually due to ignorance being left to its own resources. A watchful readiness to extend co-operation, advice, information and assistance in matters which come within our scope will help to correct this.

It is likely, however, that we shall come more frequently in contact with agencies of a constructive nature, of which the scientific bureaus of the government may be taken as typical. These do a great work, and our respect and admiration for it is likely to be proportional to our knowledge of it. Their primary purpose coincides with our own, the assistance of the application of knowledge to industry. To a great extent their usefulness will depend upon us and our *confrères* in related lines, upon the use we make of them, upon the fertility of the suggestions they receive, upon the extent of the support of their efforts. It is so easy to take beneficial activities for granted that it is necessary continually to remind ourselves that a given amount of energy devoted to the support of existing valuable agencies will produce many times the results which would follow its application in other directions. The cultivation of many fields of investigation which would otherwise lie dormant because, being everybody's business, they are nobody's business, constitutes a peculiarly useful branch of governmental activity and we ought by suggestion and support to lend every possible assistance to those to whom it is entrusted.

The development of such relations with them would result in a duty of another description falling upon us as representing the people in these matters; in so far as such governmental activities touch upon our sphere, we should impose a measure of accountability. We should assist in checking expenditures on unnecessary work, or on duplication; we should insist, in view of the conception of bureaucratic infallibility held by the uninformed, on accuracy of statement in governmental publications, and of the elimination from them of collections of untrustworthy or incorrect information. We should carefully examine the recent tendency to regulate certain branches of industry nearly related to ours by instruction, by suggestion, even by the development of industrial processes.

Some aspects of this tendency are open to serious objections on principle; but it is evidently with us for trial at least, and we must do what is possible to encourage its useful, to discourage its harmful aspects. We should insist upon a careful checking of all statements of the commercial aspects of governmental work of this description as well as of its technical features. It is impossible to believe that governmental agencies such as I have alluded to could fail to gain in value by the inculcation of a sense of responsibility to the technical societies of the country. It would probably reduce the temptation to play to the gallery; it would at any rate prevent the deplorable spectacle of a member of the cabinet announcing a technical discovery originating in his department in terms of combined ignorance and extravagance of claim which would almost justify exclusion from the mails if employed by an ordinary company promoter.

Multiplication of instances in quite other fields of action would be easy; I have taken quasi-political cases because they afford perhaps the best illustrations, but I must turn, however, to the consideration of means, of the "adjustment of internal to external relations." The stimulus must come largely from the individual, the unofficial member. He must be ready to bring up subjects of general interest; the officers and the board must be equally ready to afford facilities for their general discussion and their thorough consideration by active and competent committees. However intense and unanimous the feeling of the membership may be upon any particular matter, the effectiveness of its expression will necessarily depend in the last resort upon the energy and ability of some committee. There is an unusual abundance of suitable committee material in this society, and there will be no difficulty in getting matters in which you are sufficiently interested properly handled. The discussion of external matters at our meetings would also tend to stimulate the exercise of the power of individual members for educating the uninformed.

Coöperation with other societies should be not only willingly given, but sought after. In general, coöperation with other societies forms an extremely important part of our external activities. Even the little which has been done has been productive of results. A single

[4] Trans. Amer. Electrochem. Soc., 16, 3, (1909).
[5] Cf. Met & Chem. Eng., 11, 117 (1913).

joint meeting, for instance, with the Electroplaters' Association some years ago has not only led to a considerable increase in interest in electroplating work in our own society, but has given the impetus to some very interesting and promising developments in electroplating circles in more than one locality. But the most interesting steps in inter-society coöperation have been taken for us by our flourishing New York Section during the last few years. We are indebted to that Section and to its capable chairman for showing us to what extent many dominant subjects need joint sessions for their proper presentation and discussion; and that brings me to the suggestion that the encouragement of local sections is the readiest means of fostering a healthy internal and external development. By their very nature they are able to maintain a much more continuous chain of interest; they come more readily in contact with the problem of the moment, the external problem; they touch it with less hesitation, less formality.

I cannot conclude without expressing my admiration of the excellent example which the editor of "Metallurgical and Chemical Engineering" has set us in the editorial pages of his journal; pages which have often so thoroughly represented the society in external affairs that we may very well be pardoned, though not excused, for having felt any exertions on our part possibly superfluous.

Notes

The Caloris Company announces the removal of their factory from Philadelphia to Millville, N. J. There it is located along their own glass house so as to provide better facilities for handling orders for glass tubes, laboratory glass ware, etc.

The **Oneida Community, Ltd.**, makers of the well-known Community Silver Plate, have completed and equipped a new factory at Kenwood, N. Y., and have now transferred the last of their various departments from Niagara Falls, N. Y., to this new plant. This move was made necessary to avoid the deleterious effects on the silver plate of the fumes from various chemical companies in the vicinity. It is said that the Niagara Falls plant which they have vacated is especially suitable for electrochemical work and may be leased on very advantageous terms.

The **Buffalo Forge Company**, of Buffalo, N. Y., has recently issued three interesting new catalogs. No. 200 relates to the "Buffalo planoidal fans," a modification and improvement on the older type of steel plate heating and ventilating fans with a comparatively small number of radial blades. With the improvements in design embodied in it, this type of fan is expected, for many conditions, to compete on an equal basis with the multiblade fans. Catalog 201 relates to "Niagara conoidal fans." Besides having all the advantages of the multiblade type in respect to higher operating speeds, more compact arrangement, and greater rigidity, the shape of blades and proportion to the housing used in the Niagara Conoidal, make it possible to convert into static pressure the velocity head, which is much higher proportionately to the total pressure with multiblade fans than with types having few blades. Catalog 182-E is a summary for convenient reference of the various types of blowers and exhaust fans, which are regularly built for direct connection to motors. This includes everything from large ventilating and drying fans down to the little Baby Conoidals for ventilation of moving picture booths, drying cabinets, etc., and electric blowers for single forge fires, which take less than half the horsepower of an ordinary electric lamp.

Hardinge Amalgamator.—The Hardinge amalgamator is a new invention of Mr. H. W. Hardinge, president of the Hardinge Conical Mill Company. While a full technical description is being withheld until the patents have been issued, the amalgamator is being tried in several Western mills. The adjoining diagram shows balls of gold amalgam (containing 50 to 60 per cent gold) from the Hardinge amalgamator

BALLS OF GOLD AMALGAM FORMED IN HARDINGE AMALGAMATOR

attached to the 8-ft. x 22-in. Hardinge pebble mill in the Plymouth Gold Mining Company's plant at Plymouth, California. These amalgam balls are formed by rolling around in the amalgamator and picking up small particles of gold in conjunction with mercury.

The Money Value of Radiated Heat.—In the Chamber of Commerce Building, Detroit, Mich., a retail store room is located directly over the boiler room and the heat from the latter was quite objectionable. In order to decrease the radiation of heat from the boilers and steam lines the engineer of the building insulated the settings and steam drums with Nonpareil Insulating Brick and recovered some of the steam lines and pump cylinders with Nonpareil High Pressure Covering. The cost of the Insulating Brick and Steam Covering was $214.84 and the application was made by the regular crew at odd times. Not only was the temperature above the boilers reduced 30 deg. by the use of this insulation, making conditions far more comfortable in the store above, but it was found that heat losses were reduced to such an extent that one boiler would carry the load which formerly required two. As the load in this plant varies but slightly it was an easy matter to obtain the fuel savings by comparing the records of coal consumption before and after the insulation was installed. In 1913, before the insulation was applied, the coal consumption in the six months from April to September was 224,960, 229,950, 218,790, 238,120, 224,630, 211,490 lb. respectively or a total of 1,347,940 lb. For the corresponding period in 1914, after the insulation was installed, the consumption was 183,190, 181,930, 180,690, 179,470, 176,000, 174,290 lb. or a total of 1,075,570 lb. This shows a net saving of 272,370 lb. of coal—136.185—tons costing $2.95 per ton. This is equal to $401.75 or over $800 per year—nearly four times the cost of the insulating materials, which were responsible for this saving.

The Spanish Government has prohibited the exportation of potash.

New Orleans Meeting of the American Chemical Society

Symposium on the Contributions of Chemistry to the Industries of the United States

The fiftieth meeting of the American Chemical Society was held in New Orleans, La., from Wednesday, March 31, to Saturday, April 3. Southern hospitality made the meeting a notable and highly successful and delightful event in the history of the society. The chairman of the local committees in charge of the different functions at the meeting were Messrs. W. L. Howell, C. S. Williamson, Jr., B. P. Caldwell, J. L. Porter, P. Asher, G. B. Taylor, L. A. Becnel, S. J. Tremoulet, and Mrs. E. J. Northrup.

The hotel headquarters were at the Grunewald Hotel, where many of the sessions were held. But the opening session, with the symposium on contributions of chemistry to American industries, was held in Gibson Hall, Tulane University, on Thursday morning, April 1. The attendance at this session was about 250.

President Charles Holmes Herty called the meeting to order and speeches of welcome were made by Mayor Martin Behrman and President Robert Sharp of Tulane University. President Herty replied for the Society.

Then Dr. Arthur D. Little of Boston, Mass., started the symposium with a very able address on "the industrial resources and opportunities of the South." The presentation of papers on contributions of chemistry to nineteen different American industries followed. The lecture by Dr. Bernhard C. Hesse of New York in the evening may be considered as the conclusion of the symposium. This lecture was delivered at the Hotel Grunewald.

CHARLES HENRY HERTY, PRESIDENT
AMERICAN CHEMICAL SOCIETY

SOCIAL FUNCTIONS AND EXCURSION

On Wednesday a smoker on the steamboat Sidney on the Mississippi river was greatly enjoyed by 300 members and guests including ladies. The cabin of the boat was festooned with smilax and gray Spanish moss. It was a very pretty Southland scene. A darky band furnished the music. Dinner was served. There was an entertainment afterwards and, of course, dancing. The party returned to New Orleans at 10 p. m.

On Friday evening a banquet was held at the restaurant de la Louisiane. The attendance was 200. Messrs. Alciatore served a real Creole dinner. Professor B. T. Caldwell of Tulane University was toastmaster and addresses were made by President C. H. Herty, Dr. W. L. Howell, Dr. C. L. Alsberg and Dr. C. L. Parsons.

There were some very interesting excursions during the convention week.

On Wednesday afternoon a party of 30 went through Henderson's sugar refinery.

On Friday afternoon a visit was paid to the New Orleans water purification plant by the Water, Sewage & Sanitation Section. About 50 members were taken to the plant in automobiles.

On Saturday afternoon a party of 20 visited the sugar refinery at Chalmette, while another party devoted the whole of Saturday to an excursion to the Weeks Island salt mines. About 110 took part in the excursion. The hotel was left at 7.15 a. m. in special cars and a special train of the Southern Pacific was taken at Algiers depot. Drs. Baekeland, Herty, Hillebrand and Parsons were in the party. The island was reached at noon. It is a knoll or lump about 150 feet above gulf level. The party went down into the mine, 600 feet below the surface, 20 at a time. The area of the mine is at present 20 acres. No timber is used in the mine construction. The salt is blasted down—pure rock salt crystals of 99.99 per cent purity. There seems to be an almost unlimited supply. The Myles Salt Company operates the mine. The hospitality of the place was tendered personally by Mr. Beverly Myles. The party left the salt mine at 3 p. m. and reached New Orleans at 8 p. m. It was a delightful day.

SECTION MEETINGS

On Friday meetings of the different divisions were held all day long at the Grunewald Hotel and fairly well attended. 153 papers were presented.

There are now eight sections of the American Chemical Society as follows:

Agricultural and Food Chemistry, Secretary, G. F. Mason, H. J. Heinz Company, Pittsburgh, Pa. Chairman Floyd W. Robinson was in charge.

Biological Chemistry, Secretary, I. K. Phelps, Bureau of Chemistry, Washington, D. C. Chairman C. L. Alsberg was in charge.

Fertilizer Chemistry, Secretary, F. B. Carpenter, Virginia-Carolina Chemical Company, Richmond, Va. Chairman J. E. Breckenridge was in charge.

Industrial Chemists and Chemical Engineers, Secretary, S. H. Salisbury, Jr., Lehigh University, South Bethlehem, Pa. In absence of the chairman, G. P. Adamson, the proceedings of the section were in charge of H. E. Howe.

Organic Chemistry, Secretary, C. G. Derick, 619 Indiana Ave., Urbana, Ill., who presided in absence of the chairman.

Pharmaceutical Chemistry, Secretary, A. P. Sy, University of Buffalo, 24 High Street, Buffalo, N. Y. Chairman F. R. Eldred was in charge.

Physical and Inorganic Chemistry, Secretary, R. C. Wells, U. S. Geological Survey, Washington, D. C.

Water, Sewage and Sanitation, Secretary, Harry P. Corson, State Water Survey, Urbana, Ill. Chairman Edward Barton was in charge.

The Industrial Resources and Opportunities of the South

The symposium on Thursday was introduced by a fascinating address by Dr. **Arthur D. Little**, of Boston, Mass., on the industrial resources and opportunities of the South.

"Only those who have stood upon the seashore and there endeavored conscientiously to place the Atlantic Ocean inside a quart bottle by the aid of a teaspoon will appreciate the temerity and difficulties involved in an attempt to present within the compass of a brief address the industrial potentialities of the South. Probably no one but a relative stranger to the South would make the attempt at all.". . .

"The awful spectacle of a world in arms which we are forced to contemplate today must recall with peculiar vividness to many men and women North and South the horrors and desolation of another struggle which was concluded, happily as we all now believe, just fifty years ago. When we consider that the wealth of the whole United States in 1850 was estimated at a little more than $7,000,000,000 and that the cost of the war to the South has been conservatively figured at $4,000,000,000, we may gain some faint notion of the material burden under which the South slowly arose to work out her destiny."

ARTHUR D. LITTLE

RESOURCES OF THE SOUTH

After giving some statistical figures, Dr. Little pointed out that agriculture is still and always will be the greatest business of the South and the backbone of its prosperity, although even now the value of manufactured products exceeds by nearly $90,000,000 the revenue from its farms.

As all the world knows, the South affords a peculiarly favorable habitat to the cotton plant and the 36,000,000 acres under cotton produce annually from 14,000,000 to 16,000,000 bales of the fibre, or about 65 per cent of the world's crop. In this connection it may be said in passing that chemists by developing methods for utilizing values in the cotton seed have added from $12 to $14 per bale, or perhaps $200,000,000 yearly to the value of this single crop, so that the seed alone is now worth nearly as much as the entire crop of 1860. Cotton and seed together constitute about 30 per cent of the total value of Southern farm products, excluding live stock. The ultimate products of the cotton plant together constitute 30 per cent of the merchandise exports of the Whole United States. The value of staple, linters and seed in 1913 was $911,000,000. Corresponding values for 1914 were $704,000,000, so that the European war may fairly be said to have cost the South, on this one item, over $200,000,000.

Strangers to the South do not commonly think of this portion of our country as a manufacturing community. They may, therefore, well be surprised to learn that already the manufactures of the South greatly exceed in value the products of its farms and reach the stupendous total of more than $4,000,000,000. In the 29 years from 1880 to 1909 the capital invested in the South in manufactures increased 900 per cent and the value of manufactured products 407 per cent. The census survey of the entire country enumerates 262 different lines of manufacture. Of these 236 are already carried on in the South.

The annual value of Southern lumber is about $350,000,000, but the reported cut excludes so many primary wood products of larger importance that at least another hundred million dollars must be added to represent their value and $25,000,000 more for naval stores.

Excluding lignite, the coal areas of the Southern states amount to about 88,000 square miles, or over 50 times the coal area of Germany, seven times those of Great Britain and twice those of all Europe, including Russia. The South's present proved reserves of coal are estimated at 530 billion tons, or 25 per cent more than the more thorough exploitation of all European countries has disclosed—and these Southern reserves comprise 75 per cent of all the coking coal in the United States. West Virginia alone has a far greater coal area than Great Britain and Germany combined, and she has mined less than 1/6 of one per cent of the 150 billion tons beneath her surface. Nevertheless, her 1912 output of 67,000,000 tons was 50 per cent more than all bituminous coal mined in the United States in 1880. Alabama already stands next to Pennsylvania in coke production.

With coal, limestone, and iron ore closely adjacent within her borders, Alabama has already demonstrated her ability to manufacture pig iron more cheaply than any other locality on earth and "he who has the iron will get the gold." Her present output of 2,000,000 tons is merely an earnest of her potentialities. The immediately available Southern iron ores are estimated at 2,600,000,000 tons, with even greater reserves of ores of lower grade. Together these constitute not less than 50 per cent of the total iron resources of the country.

It is doubtful if any American product is better known throughout the East than those tins of kerosene which bear the label of the Standard Oil Co. In 1890 the South produced less than half a million barrels of petroleum. In 1912 its output was 84,000,000 barrels. Passing by the great deposits of Louisiana and Texas, it may be pointed out that the oil production of Oklahoma alone in 1911 was 54,000,000 barrels.

More than 60 per cent of the natural gas output of the country must be credited to the South. About 5,000,000 hp in water power is available in the South and only about one-fifth of this power has been developed, and of this amount nearly 800,000 hp is in the five states of Alabama, Georgia, North Carolina, South Carolina and Virginia. Georgia alone has available 500,000 hp.

The lavishness with which Nature has bestowed her gifts upon the South is nowhere more apparent than in the extraordinary variety and range of what may be termed the secondary mineral resources of this fortunate section of our country. An output of $5800 worth of diamonds per week of the best South African quality in Pike County, Arkansas, is interesting and promises to become spectacular, but it shrinks to insignificance before many other Southern mineral products. The whole country knows the annual shipment of 8,000,000 boxes of Florida oranges and grapefruit, but relatively few of us give thought to the three million tons of the infinitely more important phosphate rock which Florida produces. This is about four-fifths of the country's output, practically all of which now comes from the South.

Portland cement requires for its manufacture an assured supply of limestone and clay or shale adjacent to cheap fuel. Nowhere are these conditions met more fully or more generally than in the South. As a result, its development of the manufacture of Portland cement has become one of the industrial miracles of the world. In 1890 the production for the whole United States was less than 400,000 barrels. In 1911 the output of cement in the Southern states alone was nearly 11,000,000 barrels.

Then the South has clays, gypsum, bauxite, sulphur. The largest sulphuric acid plant in the world is at Ducktown, Tennessee, but the striking feature of the installation which holds this record is that the acid is made from smelter fume, which commonly in other plants goes only to create a nuisance. The copper production, which is the primary output of the plant, is over 18,000,000 lbs. per year. The largest copper refining plant in the world is at Patapsco, Maryland, with an annual production of 200,000,000 lbs.

In 1911, 42 per cent of the lead output of the country came from the South and 41 per cent of the zinc production. The value of Missouri zinc alone was $14,000,000. The largest pyrites producing plant in the whole country is in Louisa County, Virginia.

THE FAILURES OF THE SOUTH

What are the failures to be charged against the South? First of all, there is the stupendous failure of its agriculture. In 1909 only about 18 per cent of the total area of the South was tilled, whereas 75 per cent is available for tilled crops. What is more to the point, the 110,000,000 acres which were tilled were tilled badly.

Next, perhaps, in importance is the failure of Southern lumbering, which is one of the most wasteful operations conducted on the whole broad face of the Earth. Upon a cut of 30,000,000,000 feet of yellow pine the South wastes not less than 15,000,000,000 feet, which intelligently utilized as raw material should yield ten times the profit derived from lumbering.

Then there is the enormous waste in natural gas. The waste of gas in the Oklahoma fields alone has been as high as 150,000,000,000 cubic feet a year, and is now annually not less than 25,000,000,000 cubic feet. Every 100,000,000 cubic feet of natural gas represents on the basis of a ten-hour day 588,000 horse power, if consumed in a fair gas engine on fluctuating load averaging 50 per cent of rated capacity.

The South contains over 50 per cent of the total iron resources of the country. Nevertheless, it produces only 12½ per cent of the pig iron made and consumes not over 150 lbs. per capita, while the figure for the whole country is 650 lbs. Here again we have before us the fundamental difficulty which confronts the South. A ton of iron ore shipped as ore returns only $2 and provides less than one day's work for one man. If shipped as stoves it returns $40 and has provided a day's work for ten men. The South has been selling raw materials. It should sell brain values and labor values.

Owing to its later advent as a large producer and its relatively more general introduction of by-product coke ovens, the South has been less wasteful than the North of the ammonia values in its coal.

An excellent example of intelligent conservation is afforded by the great pulp mill at Canton, North Carolina. Formerly the spent chips from the chestnut extract plants were burned. Now they are boiled in caustic soda and converted into high-grade pulp and paper.

One of the greatest of the relatively undeveloped potential industrial assets of the South is undoubtedly the negro. Scarcely any work carried on in the South today is more truly constructive or fraught with greater ultimate possibilities than that which goes forward at Tuskegee and in those other institutions of which it is the type.

THE GOAL OF THE SOUTH'S DEVELOPMENT

The first of the South's problems would seem to be the organization of rural life to make it richer, more satisfying, more profitable and pleasanter. It is bound up with the problem of the reorganization of Southern agriculture. *The South has really not begun to farm.*

Foremost among the industrial problems of the South would seem to be the suppression of wastes, the vastly greater development of labor values in its products and the keeping at home of money now needlessly spent elsewhere. The South has been too generally content with shipping crude materials and primary products and too ready to accept from other sections the things which it might better produce at home.

For gigantic wastes which may immediately be utilized to the enormous profit of the South no industry is comparable to the lumbering of yellow pine.

While Northern paper mills are paying on the average $18.37 for the wood to make a ton of paper, the South is throwing away tens of thousands of cords of pulp wood every day, only a cord and a half of which is needed to make a ton of Kraft paper, worth $70. The ultimate development of a vast paper industry in the South is assured. But men are needed—captains of industry.

"Several types of gas producer are now operating profitably on wood waste. New methods of controlled distillation have been developed and applied to wood, and it has been proved both by the Forest Service and our own laboratory that turpentine and rosin may be profitably extracted from stumps and lightwood by processes which permit the manufacture of paper from the extracted chips. The production of lumber in the South will ultimately become a mere incident in the business of lumbering. No longer then will logging tramways be pulled up the moment the saw logs on the tract have been removed. They will stay until the tract is cleared of cord wood, pulp wood, lightwood, stumps, and saw logs. The cleared land will be devoted to grazing or to farming under the stimulus of demonstration farms or corporation management and the lumber mill become the center of a whole group of highly profitable industrial activities.

"Less than 30 per cent of the lumber produced in any Southern state receives any further industrial handling in the state of origin. Cotton seed oil is shipped to Chicago and to Berlin, New Hampshire, to be hydrogenated and converted into lard and butter substitutes. Bauxite is sold for $5 a ton to be subjected elsewhere to the purifying treatment, which raises its value to $60. The South will one day benefit enormously by a cheap process of producing alumina direct from clay. It will give new values to Southern clay beds and to Southern water powers and transfer the aluminum industry to this section. It does not appear, however, that any effort is being made in the Southern states to develop such a process.". . .

"No locality in the United States, and perhaps none in the world, presents such advantages for the establishment of the great basic chemical industries as Louisiana. Here in close juxtaposition are found cheap salt, even cheaper sulphur, gas, oil, rosin, turpentine and wood waste, while nearby are the coal and minerals of Arkansas and Alabama.

"It is noteworthy, in view of the extraordinary opportunities for chemical development presented by the South, that in the Southern states are to be found only about 10 per cent of the chemists of the country as represented by the membership of the American Chemical Society.". . .

"Fragmentary and utterly inadequate as this attempted presentation of Southern resources has proved to be, it will have served its purpose if it has brought freshly home to some of you who live in this supremely favored section of our country the responsibility for individual initiative imposed upon you. Opportunity implies responsibility. Gentlemen, you are heirs to an imperial inheritance and its responsibilities are yours."

Contributions of the Chemist to Various American Industries.

After Dr. Little's very able address the symposium of papers on the contributions of the chemist to nineteen different American industries was begun. These nineteen papers were presented mostly by others than their authors. Dr. Baekeland read Mr. Ash's paper. The meeting adjourned at 12.30, when Dr. Horne's paper had been reached. Dr. H. A. Houston's illustrated lecture on the potash industry of Stassfurt occupied the afternoon session and the other papers of the symposium were presented on the next day in the convention hall at the Grunewald Hotel. Advance copies of the symposium papers were available. We herewith give a concise resumé of all of them.

Contributions of the chemist to the **California wine industry** were covered in a paper by **Charles S. Ash.** The chemist began to be of value to the wine industry only when he became familiar with the wine business and became a wine man. One of the chief problems he has solved is to assure the stability of the wine. Preservatives were first used, such as salicylic acid and benzoic acid, but the pure food laws have stopped this, and all attempts looking for a preservative that cannot be detected, have been in vain. But what the chemist has done in solving the problem of the production of a stable wine is the establishment of the fact that by proper methods of handling the use of preservatives becomes unnecessary. Further, by chemical control of the "blending" operation, he has insured the uniformity of the product as completely as seasonable difference will allow. Moreover, by chemical control, he has reduced the spoiled wine from 25 per cent to less than 1 per cent (about 0.46 per cent average). Finally he has reduced the quantity of inferior wine from 25 per cent to 5 per cent. (Some grapes always give inferior wine no matter what care is given to the products). In spite of earlier temporary discouragements, the wine chemist is now having more intimate relations to the wine industry.

The contributions of the chemist to the **copper industry** were the subject of a paper by **J. B. Francis Herreshoff,** vice-president of the Nichols Copper Company and consulting engineer of the General Chemical Company. The output of copper in the United States was 17,500 long tons in 1874; 64,708 in 1884; 158,120 in 1894; 362,739 in 1904; and 563,700 in 1912. It was not until after 1890 that the real value of chemists in improving operations in mining, as well as in concentrating, roasting, smelting, and refining copper was fully appreciated. Chemical analyses permit chemical control of concentration as well as of roasting and smelting. The United States mines produce more than 50 per cent of the copper of the world; 75 per cent of the copper of the world is refined in this country and the larger proportion of this refining is done by electrolysis. In carrying on this electrolytic work, the chemist has been responsible for a very large proportion of the improvements that have been made in the last 20 years. Copper wire for electrical purposes must be of highest purity such as can only be obtained by electrolysis; for instance, a quarter of one per cent of arsenic in copper cuts down its electrical conductivity from 101 to 45.

Contributions of the chemist to the **corn products industry** were discussed in a paper by **E. T. Bedford,** president of the Corn Products Refining Company. The industry of glucose and grape sugar, or, as it is known in this country, the industry of corn products, is based upon an epoch-making discovery of a chemist—the conversion by chemical means of starch into reducing sugars. Owing to the character of the raw material employed in this country—corn—the products are no longer limited to two; the chemist has added to them until their number now exceeds one hundred. The corn manufactured into corn products in this country amounts to 50,000,000 bu. per year. It is converted into 800,000,000 lb. of corn syrup, 600,000,000 lb. of starch, 230,000,000 lb. of corn sugar, 625,000,000 lb. of gluten feed, 75,000,000 lb. of oil and 90,000,000 lb. of oil cake.

The chemist soon recognized the large possibilities which lay in the utilization of certain constituents of the raw material which were allowed to run to waste. First among these were the nitrogenous substances, commonly classified under the name of "gluten." Their running to waste was dropped; the product was collected, washed and dried, and put upon the market as a cattle feed. The recovery of the outer hull of the corn, the bran, and the development of the corn oil industry followed.

Contributions of the chemist to the **asphalt industry** were the subject of a paper by **James Lewis Rake,** secretary of the Barber Asphalt Paving Company. Chemistry, in the service of the asphalt industry, has converted it from one which originated on purely empirical lines into one which is now founded on a rational and highly scientific basis. The chemist has given his assistance in the preparation of fluxes or heavy oils of suitable character, and in the fixing of a standard for the grading of the sand and the nature and amount of filler or powdered stone which enter into an asphalt pavement. Aside from this, he has studied the nature of the native bitumens which are the components of asphalt and has differentiated the various types which are found in nature. In fixing the characteristics of the asphalts and the various petroleums from which fluxes and residual pitches are obtained, he has made it possible to describe these materials with such accuracy in specifications that they are readily differentiated.

The contributions of the chemist to the **cottonseed-oil industry** are covered in a paper by **David Wesson,** manager of the Technical Department of the Southern Cotton Oil Company. The industry was started in the fifties of the last century by one or two mills in New Orleans. In 1872 as much as 52,705 tons of seed were crushed. This amounted to 4 per cent of the entire crop of 1,317,637 tons. In 1913, with a production of 6,305,000 tons 4,767,800 tons were crushed, or 75.6 per cent of the entire crop. The estimated average cost per ton was $25.35, and the total value of the seed alone was $120,850,000, while the value of the products was $156,600,000. About 1890 "chemistry began to take the industry in hand. Crude oil, up to now, had been bought and sold as prime, or prime for the season, or off, and was passed upon by manufacturers and brokers, who looked at it, tasted it, then looked wise and gave their verdict. Then the chemist stepped in and found that the quality of the oil closely followed the free-acid present, and started grading accordingly. This made a big stir. Some of the mill owners denied the possibility of free fatty acid being present in any of their oil, as they never had any fatty acids on their premises. The chemists then showed these same mill men how much oil they were losing in their cake and throwing away in their hulls, with the result that more oil was made per ton of seed.

"The hulls were burned under the boilers and furnished the power for the mills. Every ton of seed furnished about 700 lb. of hulls. The ashes, averaging about 10 lb. per ton of seed were a valuable by-product, being rich in potash and phosphoric acid.

The writer is in doubt whether it was a chemist or a cow that discovered that hulls were good for cattle food. At any rate, cows ate them with avidity, and analyses proved that they had the feeding value of low-grade hay. So the mills now get from $4 to $10 a ton for hulls which were worth about $1 to $2 per ton as fuel.

"The cotton-seed soap stock in the early days was almost thrown away. Much was made into woolen and scouring soaps. About 1877, a bright near-chemist mixed some of this soap with soda ash, and made it into washing powder. The advertising man made a virtue of its yellow color, and the 'twins did the work.' Now, the soap stock is used as a source for white distilled fatty acids and glycerine, while the residual tar from the stills forms a base for paint and roofing materials."

But the chemist's greatest service to the industry has been in the refining of the oil. His achievements are summed up as follows: He has put the refining of crude oil on a more rational basis and prevented loss in manufacture by making a physical audit by analytical methods of the work of mills and refineries. By analyses of products their values have been shown, and the commercial practice has been placed on an accurate foundation. By improving refining methods, practically all cottonseed oil, regardless of section, or season, has been converted into one of our most valuable food products, and the residue worked into valuable by-products. By the new process of hydrogenation wholesome edible fats of the consistency of butter and lard are now produced entirely from what will probably continue to be our cheapest vegetable oil. While the chemist has worked to improve the manufacturing side of the industry, he has been the means of putting something like $125,000,000 every year in the hands of the farmers; or, in other words, he has added ten to twelve dollars to the value of the crop for every bale of cotton grown and has made possible an industry which provides means of livelihood for the thousands of people in hundreds of factories and on the road making and selling the products.

Contributions of the chemist to the **cement industry** were the subject of a paper by **G. S. Brown,** president of the Alpha Portland Cement Industry. "The tremendous advance made in this industry has been, for the most part, due to the zeal and knowledge of the chemist." Portland cement has been manufactured in Europe for very many years and in the latter part of the nineteenth century was imported into the United States in large quantities. Then by chemical research it was established that with the materials available in this country it was possible to manufacture cement really of a better quality than that hitherto imported. A broader field was opened by reduction of the cost in manufacture, due to the use of powdered coal as fuel, the increase in the size of the kilns, and the handling of the raw material in large quantities direct from the quarry. Further work has been done by the chemist in the working out of standard specifications, in the development of a water-proof cement, etc. "The fact that the chemist is responsible for the quality of the cement to such an extent that he controls the operation of the mill, is largely advertised by at least one of the larger cement manufacturing companies in the United States."

Contributions of the chemist to the **sugar industry** were discussed in a paper by **W. D. Horne,** who reviewed the past, present and future. In the manufacture of raw sugar, the past quarter century has seen great advance through bringing factories under chemical control, and the cane industry has caught up with and surpassed the beet industry through its scientific development on these lines. The consumption of sugar in the United States has risen from 1,500,000 tons in 1890 to 3,750,000 tons in 1914 and the per capita consumption from 54 lb. to 84 lb. per year. This has been partly due to the cheapening of sugar through scientific management in its production, raw sugar having fallen from 2.88 cents per lb. (without duty) in 1890, to 2.03 per lb. in 1914, and this, too, in spite of a rise in price of all other food staples, averaging considerably over 15 per cent.

In making raw sugar the proper defecation and clarification of the juice are chemical matters of first importance and during twenty-five years great improvements have been made in the double carbonation process both for beet and cane, the use of sulfitation of the thin carbonated juice, and the use of phosphoric acid and its salts as additional defecating materials. Kieselguhr has been introduced by Wiechmann as a clarifying agent and is now being used more and more extensively, especially since the development of the great Lompok deposit in California. Raw sugar factories are now producing white sugar directly from cane as well as from beet, due to chemical investigations of the matter and chemical control.

Raw sugar factories are now generally able to sell their molasses instead of throwing it away, because of chemically developed methods of converting it economically into alcohol, cattle foods when mixed properly with bagasse, peat moss, etc., and into other useful products. The sugar is all recovered from beet molasses by the Steffens process of conversion into tricalcium saccharate, and the by-products from this are going into fertilizers, cyanides, etc. Wax is recovered from scums and the residues utilized as fertilizers in the cane fields. Paper is made from the unused fiber of the cane and another by-product has been improved by the chemical investigations of the manufacture of rum.

In sugar refining, due to chemical research, invention and control, progress has been made all along the line. This and another work done in many laboratories is concisely sketched in the paper and the author concludes that the future contributions of chemistry to the sugar industry will probably be found in simplified processes of defecation, cheapened materials for color removal, etc., more energetic chemical treatment of low-grade products and a better utilization of such by-products as are inevitable.

The contributions of the chemist to the **incandescent gas-mantle industry** were discussed in a paper by **Sidney Mason**, president of the Welsbach Company. "No article more strikingly emphasizes the importance of the science of chemistry than does the incandescent gas mantle, which owes both its inception and development, up to the towering output in the United States alone of upwards of 80,000,000 mantles annually, to the untiring effort of chemical research." The paper was naturally a concise summary of the work of Auer von Welsbach and his coworkers.

Contributions of the chemist to the **textile industry** were discussed by **Franklin W. Hobbs,** president of the Arlington Mills, and past president of the American Cotton Manufacturing Association. He sketched the contributions of chemistry to bleaching, dyeing, the production of dyestuffs, mercerization of cotton, and manufacture of artificial silk. "The annual production of artificial silk is now fully 20,000,000 lb. There are various processes—collodion, gelatine and viscose. The viscose process now seems to command the field and is developing rapidly in quantity and

quality produced. Here is a case where common wood pulp worth a few cents a pound, by a touch of the chemist's art, is changed to a beautiful silk-appearing yarn worth from $2 to $3 a pound."

Contributions of the chemist to the **fertilizer industry** were discussed in a paper by **H. Walker Wallace**, manager of the general sales department of the Virginia-Carolina Chemical Company. The chemist discovered the necessity of the industry by studying the composition of soils and plants. He first suggested the production of superphosphate and established its manufacture. The process of manufacture has been gradually improved so that the insoluble phosphoric acid has been reduced from two to three per cent to a fraction of one per cent. He was responsible for the manufacture of sulfuric acid, which is necessary for the production of superphosphate. He has produced a double superphosphate containing from 45 to 50 per cent available phosphoric acid. His researches have made it possible to convert many waste products into valuable plant food constituents, which are utilized in fertilizers. The nitrogen of the air has been combined and converted into forms suitable for plant nutrition. The chemist has worked out processes for saving the nitrogen in flue gases and coke ovens and converting it into sulfate of ammonia. He has worked out formulas and blended the various fertilizer constituents into the compounds best suited for different soils and crops.

Contributions of the chemist to the **soda industry** were discussed in a paper by **F. R. Hazard**, president of The Solvay Process Company. The role of the chemist in industrial operations is to answer the question "why?" The chemist is the enemy of rule-of-thumb methods. He is not content to accept the superstitions and prejudices which have been handed down in all industry, but seeks to ascertain the causes underlying the effects which, in some cases at least, are produced with a considerable degree of regularity by the rule-of-thumb methods. It is only within the past twenty-five or thirty years that the chemist has been admitted as an important member of the manufacturing staff in our modern industrial life. Formerly the managers and owners of the business knew very little about the practical operation. They relied upon the secret formulas of the foreman. It is easy to see that the advent of the chemist was attended with great difficulties. He was regarded as their natural enemy by superintendents, and was looked upon with distrust by workmen. His experiments were ridiculed and not infrequently were purposely interfered with, so that their results would be without value. Thus early in his introduction into the industrial field, it became absolutely necessary for the chemist to tell the workmen, the superintendent, the manager, or owner, that none of them really knew their business, which unfortunately was the fact. . . . "The chemist must, therefore, exercise the patience of Job, he must have the wisdom of the serpent and the gentleness of the dove; he must be persevering and constantly alert to see the first signs which will lead him toward the answer to his question."

"As an illustration of the delicate position of the chemist toward the manufacturer, the following is taken from our own experience: About twenty-five years ago a soap-maker complained that 58 per cent alkali purchased from us was not as good for his purpose as 48 per cent alkali imported from England. After considerable correspondence it developed that his method of ascertaining this peculiar fact was to take, say, 100 lb. of each quality of alkali, dissolve each by itself in about a barrel of water and then determine the specific gravity of the solution by means of a Twaddle hydrometer. The 48 per cent alkali gave a somewhat greater specific gravity and he thereupon concluded that it was a superior article. As he was one of our important customers and a somewhat difficult man to deal with, it became necessary to convince him by his own methods that his conclusions were not correct. We prepared samples of several different kinds of alkali, also of common salt and of sulfate of soda, and, using the same hydrometer, we determined the density of each, whereupon it was found that on his theory it was an absolute waste of money for him to purchase alkali of any kind, as ordinary commercial sulfate of soda showed a considerably greater specific gravity than any of the other solutions. When confronted with this actual test, made on the same scale and using the same instrument as he had been accustomed to employ, our customer acknowledged, and continued for many years thereafter to make his soap by the use of our 58 per cent alkali." . . .

"Only last year, to show that the knowledge which a chemist can contribute is still of value, a complaint was made by a glass-maker that the 58 per cent alkali furnished to one of his works was inferior to that furnished at another. Correspondence developed the fact that the workmen at one point were also employed in handling lime and that the ventilation of the plant was not very good, while the conditions at the other plant were much better. The chief complaint was that the men in the one plant suffered seriously from sores; in fact, some of them were quite disabled. A personal investigation by one of our representatives showed that the unfortunate men were employed first in handling lime and then in unloading alkali, which was in bulk. The weather being quite warm and the exertion by no means easy, these men were establishing upon their own persons miniature caustic soda plants, and the resulting soreness and tenderness of the skin, if neglected, as was too often the case, led to rather serious conditions which required a long time to heal. An elementary knowledge of chemistry would have been sufficient to ascertain the cause of the difficulty."

Contributions of the chemist to the **leather industry** were the subject of a paper by **William H. Teas**, president of the Marion Extract Company. The author sketched the work of the chemist in preparing and using the different vegetable and mineral tanning materials.

Contributions of the chemist to the **flour industry** were the subject of a paper by **John A. Wesener** and **Geo. L. Teller.** The authors concisely summarize the principles of flour making. Chemistry assists in selecting and buying the grain; it helps to show the quality of the flour produced. It has supplemented mechanical processes of the mill and accomplished what had long been desired but could not be attained, in the improvement of color and baking qualities of the flour. By the introduction of baking-powder products it has made possible many delicacies in the way of pastry and biscuit and has made possible the great self-raising flour industry. It has helped to explain the intricate process of the fermentation of bread dough, has pointed out the way to fit flour for it, and has unlocked for investigating problems of bread production, which have, as yet, opened only enough to permit a glimpse of a large space filled with interesting and useful possibilities.

Contributions of the chemist to the **brewing industry** were discussed in a paper by **Gaston D. Thevenot.** In brewing biological considerations are as important as chemical ones. The influence of the

chemist makes itself felt first in the selection and preparation of the raw materials from which the beer is made. An enormous amount of energy has been expended by the chemist on the explanation and scientific control of the mashing process and great strides have been made in this field. The progress made in the fermentation of the beer during the last decades has been of the first magnitude. As far as the finished product is concerned, its clarification and sterilization have been given great attention. The problems of the disposal of former waste materials (spent grains, carbonic acid gas, yeast) have also been solved by the chemist.

Contributions of the chemist to the **preserved foods industry** were discussed in a paper by **R. I. Bentley**, vice-president and general manager of the California Fruit Company Association. A little over a century ago Appert, a French chemist, was awarded a prize by his government for discovering a process for preserving foods without the use of preservatives. Appert's process of hermetical sealing is the same in principle as that in use today by food preservers the world over. But the industry has grown to enormous proportions. New York City expends $150,000,000 annually for preserved foods—as much as that city spends for milk, bread and eggs combined for the same period.

Chemistry has enabled the food preserver to get the best materials suited to his use. A very simple illustration is that of salt—used to a large extent in the preservation of vegetables. Formerly, the preserver considered it a matter of economy to use the cheapest grade of salt that could be purchased. The chemist has shown him that some salt on the market contains injurious materials and that its use affects both the quality and appearance of products. Chemistry having already determined what grade of salt is best suited to his use, on its delivery the chemist determines whether the preserver has received what was selected. In the item of solder also, chemistry has enabled the preserver to get those proportions of metals which are best suited to his use, and on delivery the chemist tells him whether he has received what he ordered.

The services of the bacteriologist, besides the chemist, are needed in the food preserving industry to determine the best methods of processing. Among the applications of chemistry that have given the food preserver an improvement in the quality of his products is the improvement in the color of some varieties of fruit, such as berries, by the enameling of the inside of the can; also the examination of the water supply of the food preserver and the elimination of the objectionable elements in the water or the securing of a new supply. The almost complete elimination of iron in the machinery which comes in contact with the canner's products is due to the chemist pointing out the fact that the source of darkening or discoloration of the products was caused by the affinity of iron for tannin.

Chemistry has enabled the preserver to arrive at more economical methods of manufacture, particularly in the saving of labor and eliminating or reducing waste. Many fruits and vegetables are made ready for canning by immersing them for a few seconds in a solution of caustic soda, after which the fruits or vegetables are subjected to the action of fresh water sprays. In this manner the peeling is removed at a great saving in waste and labor without affecting the flavor of the fruit and vegetables so treated. By this method riper, and consequently better-flavored fruit can be handled than by the hand method of peeling. This method is now used almost exclusively on some varieties and is far more cleanly and sanitary than the old.

The most notable application of chemistry in the matter of utilizing the by-products of a food preserver is that of the pineapple waste in the Hawaiian factories. The sugar value in the waste is recovered and a syrup furnished to the preserver, whereby the use of cane sugar is almost entirely eliminated.

Contributions of the chemist to the **potable water industry** was the subject of a paper by **Wm. P. Mason**, professor of the Rensselaer Polytechnic Institute. The author sketched the development of the ideas as to what is required from a chemical analysis of potable water, and pointed out why in a large municipal filter plant a chemist and bacteriologist is continually needed on duty to prevent "pin-point coagulation" or an overdose in the use of "bleach," etc. To arrive at a complete estimate on the value of a water the chemist's knowledge is needed besides that of the bacteriologist.

Contributions of the chemist to the **celluloid and nitrocellulose industry** were the subject of a paper by **R. C. Schüpphaus.** All the applications of nitrocellulose in the arts are based on the fact that the structure of its various forms may be broken down by the action of suitable solvents. The discoverer of nitrocellulose was already in possession of its colloid solution. The differences between soluble and insoluble varieties (in certain solvents) were quickly recognized, and representatives of four great groups of solvents were known at the very dawn of the nitrocellulose industries, viz.: 1. Alcohols: Methyl and ethyl alcohols. 2. Ester: Methyl and ethyl acetates. 3. Ketones: Acetone. 4. Mixed solvents: Ethyl alcohol and ethyl ether.

With these fundamental facts to start from there began a long line of chemical activity. Among the industries developed, the manufacture of pyroxylin plastic occupies the first place, and the other developments, such as the production of photographic films, artificial leather, pyroxylin varnishes, and even artificial silk made from collodion may be regarded as offshoots from this branch. The activity of the chemist in this industry is twofold, covering research and control of operations. This is sketched somewhat more in detail in the paper and it is pointed out that there is not a factory of pyroxylin compounds of any importance in existence today that has not its busy staff of analytical, managing and research chemists.

Contributions of the chemist to the **glass industry** were discussed in a paper by **A. A. Houghton**, vice-president Corning Glass Works. Chemical research on glass was first necessitated for glass for optical purposes. The glasses originally available for optical purposes were made up of only five oxides—silica, potash, soda, lime, and lead oxide. Doebereiner (1829) introduced barium and strontium, Harcourt (1834) experimented with twenty other elements, and Otto Schott, since 1880, did very extended work on special glasses in conjunction with Professor Abbe and the Zeiss Company. Schott first used boric acid in glass, which is of greatest importance for optical glass. He developed not only optical glass, but thermometer glass, borosilicate glass for lamp chimneys, a compound glass for boiler water-gauge tubes, the Uviol glass for transmitting ultraviolet light, etc.

"America's contribution to the development of the glass industry, chiefly in methods of working and handling the molten glass, are epoch-making in character; along more strictly chemical lines creditable work has been done, as instanced by the Tiffany or Aurene glass, the selenium red, and others. Aside

from optical glass, on which a beginning is being made, the glasses produced in this country probably are fully equal in quality and variety to those produced abroad; and in some respects America is forging ahead."

Contributions of the chemist to the **pulp and paper industry** were the subject of a paper by **F. L. Moore,** president of the American Paper and Pulp Association.

It is hardly too much to state that the development of modern paper making and the enormous extensions of the use of paper in recent times have been due for the most part to the introduction of the three chemical processes by which wood fiber has been made available as a general substitute for rags. The author sketched the development of the sulphite process (which has now reached in the United States a production of over 5000 tons a day), the soda process, and the sulphate process, and pointed out how the paper and pulp industry has been vitally influenced by the new processes yielding cheap alkali and cheap bleaching powder, and other chemical inventions.

This paper concluded the symposium.

The Contribution of the Chemist to the Industrial Development of the United States

Dr. **Bernhard C. Hesse,** in a lecture entitled "The Contribution of the Chemist to the Industrial Development of the United States—A Record of Achievement," summarized the results of the chemist's work, brought out in the nineteen papers of the Symposium. For twelve of the nineteen industries covered in the Symposium the number of wage-earners and the value of manufactured products and the value added by manufacture is given in Table I*a* for the year 1909. For eighteen additional industries which make use of chemists in the control of their operations the corresponding figures are given in Table I*b*.

BERNHARD C. HESSE

For these thirty-one industries, the 0.01 per cent of chemists of our population directly affect 16 per cent of our wage-earners, 24.6 per cent of our manufactured values and 20.2 per cent of our values added by manufacture. This is a measure of the influence of the chemist upon the industrial development of the United States as a nation.

Table II gives a summary of the export trade between the United States and Germany for twenty-nine industries. The industries in which the United States is importer from Germany are given on the left hand of the table, those in which the United States is exporter on the right hand.

It is interesting to note that we sell Germany more lard than Germany sells us of potash and aniline and other coal-tar dyes put together; that we sell Germany half again as much refined petroleum as it sells us aniline and other coal-tar dyes; that we sell Germany practically the same amount of pig and scrap lead as Germany sells us of alizarin and anthracene dyes; that we sell Germany almost as much paraffine as Germany sells us of indigo, and so on through the list.

As a rule the things that we sell to Germany are from a chemical point of view, less refined, i. e., involve

TABLE I*a*	Wage-earners	Product value	Value added by manufacture
Wine	1,911	$13,120,846	$6,495,313
Copper	15,628	378,805,974	45,274,336
Fertilizer	18,310	103,960,213	34,438,293
Textiles	44,046	83,556,432	48,295,131
Canned and preserved foods	59,968	157,101,201	55,278,142
Cotton-seed oil	17,071	147,867,894	28,034,419
Cement	26,775	63,205,455	33,861,664
Sugar	20,730	327,371,780	52,523,806
Brewing	54,579	374,730,096	278,134,460
Leather	62,202	327,874,187	79,595,254
Glass	68,911	92,095,203	59,975,704
Paper and wood pulp	75,978	267,656,964	102,214,623
Chemicals (strictly)	23,714	117,688,887	53,567,351
Totals	529,823	$2,455,035,132	$897,688,496
TABLE I*b*			
Iron and steel	278,505	$1,377,151,817	$399,013,072
Petroleum refining	13,929	236,997,659	37,724,257
Lead smelting and refining	7,424	167,405,650	15,442,628
Illuminating and heating gas	37,215	166,814,371	114,386,257
Confectionery	44,638	134,795,913	53,645,140
Paint and varnish	14,240	124,889,422	45,873,867
Soap	12,999	111,357,777	39,178,359
Carpets and rugs	33,307	71,188,152	31,625,148
Explosives	6,274	40,139,061	17,328,113
Zinc smelting and refining	6,655	34,205,894	8,975,893
Turpentine and rosin	39,511	25,295,017	20,384,174
Oil cloth and linoleum	5,201	23,339,022	7,788,921
Chocolate and cocoa	2,826	22,390,222	8,867,162
Baking powder and yeast	2,155	20,774,588	11,436,603
Dyestuffs and extracts	2,397	15,954,574	6,270,923
Blacking, cleansing and polishing preparations	2,417	14,679,120	7,716,728
Wood distillation other than turpentine	2,721	9,736,998	3,861,147
Oleomargarine	606	8,147,629	1,650,997
Totals	513,020	$2,605,262,886	$829,052,389
Total for 31 chemical industries	1,042,843	$5,060,298,015	$1,726,740,885
Total for all industries	6,615,046	$20,672,051,870	$8,529,260,992

TABLE II—U. S. CHEMICAL TRADE WITH GERMANY (1913)

U. S. imports from Germany	Value in U. S. money	U. S. exports to Germany
	$75,000,000	1 Copper
	26,700,000	2 Lard
1 Potash salts	18,819,000	
	12,690,000	3 Refined petroleum
2 Aniline and other coal-tar dyes	7,290,000	
	4,970,000	4 Phosphate rock
	4,880,000	5 Oleomargarine
	4,585,000	6 Turpentine rosin
	4,460,000	7 Mineral lubricants
	3,840,000	8 Spirits turpentine
3 Caoutchouc	2,582,000	
	2,220,000	9 Crude benzine
	2,171,000	10 Beef tallow (prime)
	1,744,000	11 Nickel and nickel coin
4 Straw, esparto and other fibers; paper stock	1,649,000	12 Cotton-seed oil
	1,550,000	
5 Alizarin and anthracene dyes	1,463,000	
	1,421,000	13 Pig lead and scrap
6 Indigo	1,319,000	
	1,231,000	14 Crude and hard paraffine
	1,162,000	15 Acetate of lime
7 Platinum and allied metals	1,120,000	
8 Hops	952,000	
9 Miscellaneous volatile oils	941,000	
	903,000	16 Tin and tin scrap
10 Tin and tin scrap	900,000	
11 Potassium and sodium cyanide	845,000	
12 Chrome, tungsten, etc.	784,000	
13 Superphosphates	766,000	
	724,000	17 Crude wood alcohol
14 Beet sugar, refined	716,000	
	695,000	18 Carbides
	673,000	19 Miscellaneous volatile oils
15 Alkaloids exoquinone	672,000	
16 Toilet and tooth powders	658,000	
	656,000	20 Heavy benzine and patent naphtha
17 Lime-nitrogen, etc.	635,000	
18 Potash carbonate	632,000	
	617,000	21 Lubricants of fats and oils
	579,000	22 Beef and mutton tallow
19 Ferro-Al, Cr, Mn and Ni	567,000	
20 Potassium magnesium sulfate	509,000	
21 Gold ores	506,000	
	506,000	23 Copper alloys
22 Beet sugar, raw	492,000	
23 Aniline oil and salt	476,000	
24 Bronze and metal colors	473,000	
25 Glue	471,000	
26 Aluminum plates and metal	454,000	
27 Quinine and its salts	436,000	
	422,000	24 Portland cement
28 Terpineol and allied synthetics	409,000	
29 Gelatin	403,000	

less hard chemical intellectual work than do our imports from Germany. But this is so in our whole export and import business, not merely in chemistry.

With the record of which he has accomplished the American chemist can hold up his head with pride and self-confidence. That he has not done more is by no means due to any unwillingness. It is due in the largest part to the apathetic attitude of those in charge of the management of many of our industrial enterprises requiring chemical knowledge in their exploitation. Many of them fail absolutely in a chemical understanding of their own products and are devoid of any sympathetic contact with chemistry and with chemical points of view and therefore are incapable of, and unable to appreciate the value of chemical work or to have a wholesome understanding of the snares, the pit-falls and the tedium of chemical research.

The plea for the wider introduction of chemists into positions of managerial responsibility is, however, not to be interpreted into a statement that any kind of a chemist can do any kind of a chemical job. "In selecting your chemist for a responsible position you must look out that you do not get a square peg for a round hole, just as you would when engaging a man for any other position, but the trouble seems to be with many of those who have engaged chemists that they have not appreciated that there are chemists and chemists; they seem to have some sort of an idea that there is a magic about what a chemist does. Now, there is no magic at all. It is all plain, hard work, that calls for a lot of intellectual effort, and above all, the application of common sense which as every one knows, is a very rare article."

The second part of the lecture dealt with the criticisms of the American chemist which have been made by the daily press since the beginning of the European war on account of the fact that there is no complete American dye-stuff industry.

Broadly considered, the criticisms of the press may be grouped as follows: (1). The present shortage of dyes and inaccessibility of German producers to the American market offers an unusual opportunity for the manufacture of coal-tar dyes in this country. (2). The chemical manufacturer of this country should make those coal-tar dyes.

As to the first question, Dr. Hesse point out that there is no real shortage.

As to the second question Dr. Hesse referred to Lord Moulton's reasoning that one dollar's worth of dyestuffs is necessary to the production of $100 worth of manufactured product. The dividends declared and paid by the German dyestuff factories in 1912 are in the neighborhood of 10 per cent on the annual turn-over. For the purpose of discussion, let us assume it is 25 per cent and let us assume that the man who makes this $100 worth of manufactured product makes 10 per cent or $10 profit on that. The textile maker, therefore, makes $10 where the dyestuff maker can make 25 cents, or more likely 10 cents, if he can manufacture as cheaply as can the German. The American dyestuff and chemical manufacturer is not and has never been attracted by that possible 25 cents profit. The textile maker is spending that dollar anyhow to sombody; the American dyestuff and chemical maker does not care to make the dollar's worth of commodity. It is of no consequence to him in his business; he is making a living some other way, but the textile maker says it is a matter of life and death to him to get those dyestuffs.

An obvious question at this point is that if the dyes are so vital to the textile makers and the American dye makers will not make them, why do not the textile makers invest their money in a dyestuff plant and charge up any losses that they may sustain thereby as insurance premium to insure the sale of their goods and the profit therefrom resulting, just as they make their own soap, if need be? There is no ethical nor professional reason against their so investing their money.

"Granting that the stability of our textile and allied industries demand that these materials be produced in this country, it also follows that the financial burden and risk connected with the manufacture of the dyes should fall upon them. To this responsibility I have yet to see from the dye users of this country any adequate or sufficient answer?

"If patriotism will not induce buyers of cotton goods or sellers of cotton goods to pay more for goods made in the United States than for those made elsewhere, then why should patriotism cause the chemical manufacturers of this country to go ahead deliberately with a project in which they are sure to lose money?"

Some newspapers have suggested that the situation could be remedied by altering the policy of our patent laws by introducing requirements for compulsory working.

Dr. Hesse showed that the British working clause has been ineffective.

"The transplantation of the coal-tar dye industry to the United States is not a question of patent protection; it is nothing but an economic question, a plain matter of dollars and cents; those products can be made in this country if persons will buy those products at a fair margin of profit over the cost of domestic production, and since we know in advance that the cost of production here will be above the cost of production elsewhere, plus any prevailing duty, why should we go to the costly venture of spending millions of dollars to prove the obvious?"

"As a matter of fact, the whole world's coal-tar dye consumption is about enough to make a decent-sized business for one country. Ordinarily, it is best to do the world's work where it can be done best and to transport the products from their place of manufacture to their place of consumption. If it be necessary, for other reasons, that these products should be made elsewhere under conditions economically less favorable, then those who want those products made at such economically unfavorable place should bear the burden, but that is precisely what the dye users do not want to do; they want someone else to foot the bill.

"To bring the matter up squarely before you let me recapitulate: The 10,000 chemists in the United States are engaged in pursuits which affect over 1,000,000 wage-earners, produce over $5,000,000,000 worth of manufactured products and add $1,725,000,000 of value by manufacture each year; the business in products of and for chemical industry between the United States and Germany alone in 1913 provided 5 per cent of our total foreign business and 13.8 per cent of our balance of trade for that year. Please bear in mind that I am not by any means attempting to claim all the credit for this for the chemist; all that I ask is that his claim to recognition for intelligent, active and effective collaboration in bringing about those stupendous results be not thrown aside as worthless and that he shall not be made the target of unjust criticism because in 1914 there was a shortage of about $600,000 or 7 per cent in coal-tar dyes and because cotton dropped from 15 cents to 6 cents."

New Pyrometer and Instrument Manufacturing Concern.—The Gibb Instrument Company has been formed by Mr. W. H. Gibb for the manufacture and sale of thermoelectric pyrometers, potentiometers and the pyrochronograph. The offices of the company are in the Highland Building, Pittsburgh, Pa. Mr. Gibb has been in the pyrometer business for a number of years and is well known to the trade.

The Reburning of Lime from Alkali Waste and Other Forms of Precipitated Carbonate of Lime

BY RICHARD K. MEADE

Lime is used in a large number of chemical industries, among which may be mentioned the manufacture of caustic soda, bleaching-powder, calcium carbide, sugar, wood-pulp (by the soda process), glass and in the purification of water. In a number of these industries the lime does not enter the product at all but is obtained as a waste of the process in the form of precipitated calcium carbonate and may be converted into caustic lime again by the application of heat. Mixed with this calcium carbonate, which has been precipitated from solution and consequently is in a very finely divided state, is a large quantity of water, the latter amounting to three to five times the weight of the solid material in most cases.

Among those industries in which the lime is precipitated in the form of a carbonate, may be mentioned the manufacture of caustic soda, sugar, wood-pulp and in the purification of water. The lime obtained by most plants of the latter character, however, is small and it is only where water softening operations are extensive that sufficient carbonate would be obtained to justify an attempt to reclaim this. In the other three industries mentioned, however, the quantity of lime obtained is often very large and its recovery would represent quite an inducement provided it is done in a neconomical manner.

The disposal of manufacturing waste by dumping into streams is now causing more or less friction between the manufacturers and the communities in which they operate. Consequently in addition to the financial inducement of reconverting this waste lime into lime would be the satisfaction to the manufacturer of removing a source of contention with his neighbors. Where lime waste is pumped on low ground by the manufacturer, or is carted away and dumped, this represents a direct expense which its conversion into lime would do away with.

In the manufacture of caustic soda there is carried off with the lime sludge a certain small amount (½—1 per cent) of caustic soda, and if this sludge is converted into lime this soda is recovered, adding to the saving to be effected by the process.

So far as I know, no attempts were ever made to burn waste lime by moulding the material into bricks and burning these in an upright kiln. The rotary kiln employed by the cement industry, however, offered a means of burning the waste lime and its use here was naturally suggested by the fact that it had been employed for burning fresh water marls which resemble alkali waste in physical properties.

The attempt to burn alkali waste in a rotary kiln began about 1900 and the kiln was first employed in connection with dryers. This installation had been already tried on wet materials in the cement industry and proved a failure. The use of dryers in recovering waste was soon abandoned and the employment of long kilns following the cement practice was substituted. This, in connection with various schemes for thickening the waste sludge so as to reduce the water to be evaporated have made the reburning of the waste lime commercially profitable.

Among those industries in which lime is being recovered at one or more plants may be mentioned the manufacture of caustic soda, sugar, wood-pulp and soap. These plants have generally proved successful. Naturally, as I have said, the early attempts to convert this sludge into lime met with some mishaps, largely owing to a lack of knowledge on the part of the experimenters as to the fundamental principles of rotary kiln operation and design, but the process has been worked out on a practical basis and where lime is being purchased at a cost of over $3 per ton it will generally prove economy to put in a lime recovery plant, provided the quantity of sludge obtained is not too small.

As received from the caustic soda plant the lime sludge usually contains a large quantity of water, as we have said. It will be practically an impossibility to burn this material in this condition economically owing to the amount of water which would have to be evaporated. If this sludge is allowed to settle for twenty-four hours it is possible to drain off much of the water and the resulting thickened sludge or slurry will contain about an equal weight of water and of carbonate of lime and may be burned with an expenditure of about 800 lbs. of coal for 1 ton of lime. Should it be desired to reduce further the quantity of water there are a number of very satisfactory mechanical filters on the market and these may be employed to do this work. The installation of a continuous drum filter, the product from which would fall directly into the kiln, would prove efficient and labor saving.

In small lime recovery plants (10 to 15 tons of quick lime per day), the item of labor will usually amount to more than that of fuel and it will prove more economical here not to thicken the sludge beyond the point where it can still be handled with a pump. It is possible to handle a mixture of 55 per cent of carbonate of lime and 45 per cent of water successfully with a centrifugal pump and the mixture of half and half can be easily handled. If it is burned in this condition the material may be pumped directly into the kiln, using a valve to control the flow and allowing the excess to circulate back into the feed tank, thus keeping the consistency uniform.

Where the plant is large, however, better results will be obtained on the score of economy if thickeners such as the Dorr and suction filters of the continuous type are installed and as much water as possible is drawn from the lime sludge. By this means the water in the sludge may be reduced to 30 per cent, which will reduce the quantity of fuel required for burning to 600 lbs. of coal per ton of lime produced.

We have seen statements to the effect that lime sludge could be burned with about 500 lbs. of coal to 1 ton of lime. This figure is entirely too low and I do not know of any concern which is burning with this amount of fuel—600 to 700 lbs. of coal per ton of lime is nearer the correct figure.

Generally producer gas is used for burning lime sludge. Where available and cheap, however, natural gas or fuel oil would be superior fuels and would reduce the labor by one man per shift. Between 9,000 and 11,000 cu. ft. of natural gas (950 B.t.u. per cu. ft.) are required to burn a ton of alkali waste or from 60 to 80 gals. of oil.

The capacity of a rotary kiln burning alkali waste will vary largely with the condition of the waste when fed to the kiln as regards its water content. If properly installed, a 6 ft. in diameter kiln 100 ft. long will burn at least 30 tons of quick lime per day when working on a waste containing 45 per cent water. An 8 ft. x 125 ft. kiln on the same material will have a capacity of at least 75 tons of lime per day.

The cost of burning lime, including interest on the investment necessary and depreciation on the plant will vary between $2 and $3 per ton, depending on the quantity of waste to be recovered and the cost of fuel.

To operate the plant there will be required per shift one man to take care of the producer, one man to attend the kiln and if mechanical filters are installed from 1 to 2 men to look after these. If the slurry is pumped directly to the kiln, the first two men only are needed and indeed in very small plants one man alone may be trained to do the work with the occasional assistance of another man to place coal in the bunkers and wheel away the ashes from the producer.

The power required by the plant will amount to about 15 kilowatt-hours per ton of lime produced. That is a plant producing 25 tons of lime per day will require about 375 kilowatt-hours per day. The repairs will amount to about 15 cents per ton of lime produced and will consist chiefly of relining the lower third of the kiln about once a year and the lining of the producer about as often. Owing to the slowness with which the kiln revolves repairs and renewals to the carriers and driving gear are infrequent. The producer will require from 300 to 400 lbs. of steam at 60 lbs. pressure per ton of lime produced.

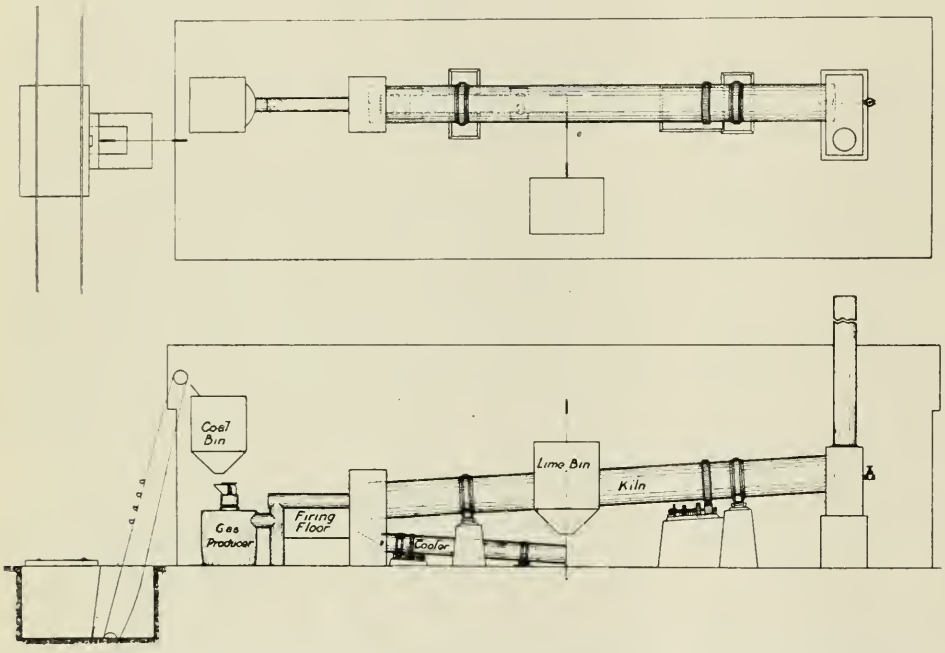


FIG. 1—PLANT FOR THE RECOVERY OF LIME FROM WASTE CARBONATE OF LIME AND LIME SLUDGE

Fig. 1 illustrates a small plant for the burning of lime sludge, which we have designed. In this plant the percentages of water in the waste is reduced to as low a percentage as will permit of the pumping of this latter. This is done by allowing the waste to settle in two large tanks (not shown in this drawing) provided with a movable syphon tube. The contents of one tank is allowed to settle while that of the other is being fed to the kiln. The sludge is allowed to settle 24 hours when the water is drained off. The slurry is then agitated by means of compressed air to remove the more solid portion at the bottom and to make it of uniform consistency, when it is pumped into the kiln by means of a small centrifugal pump. A valve controls the flow of slurry to the kiln and this valve is opened and closed by a mechanism which may be operated from the firing end of the kiln. The excess slurry goes back into the tank and serves to keep the contents of the latter agitated. The rotary kiln is of the ordinary type and if desired Z-bars may replace the fire brick in the upper end of the kiln.

The lime is obtained from the kiln in the form of small round nodules resembling very much a bird's egg in appearance and these are usually slightly colored from impurities in the lime. The lime drops from the kiln into a rotary cooler and is cooled by a current of air passing through the latter. This air is used for combustion and hence the lime in cooling serves to preheat the air.

The lime should be elevated from the cooler into a bin and it may be dumped from this into barrows and wheeled to the caustic soda plant or preferably the lime bin may be located in the caustic soda building and the material conveyed from the cooler to this by means of an elevator and screw conveyors.

The gas producer may be located at any convenient point, but should not be further away from the kiln than is absolutely necessary owing to radition losses. For a large kiln two 10-ft. gas producers may be necessary. In order to save labor the coal for the gas producer should be lifted by a bucket elevator into a steel bin above the producer and drawn from this bin to the latter as needed. This latter should be sufficiently large to hold twenty-four hours' run for the producer or if the plant is small at least a carload of coal.

The cost of a plant for the recovery of lime sludge will vary entirely with the size plant to be erected, fuel employed, class of construction used, etc. A small plant may be put up for about $12,000 to $15,000, which will have a capacity of about 10 tons of lime per day. A plant for 25 tons per day will cost about $17,000 to $20,000 and one for 40 tons of lime per day approximately $20,000 to $25,000. If oil or natural gas are to be used for a fuel the cost will be materially less, while the cost will be increased somewhat by the installation of continuous mechanical filters, etc.

Recovered lime consists of small, slightly oval lumps ranging in size from that of a walnut down to dust. The color is usually slightly yellowish or greenish. The lumps slake slightly slower than rock lime and consequenty causticise somewhat slower, but this is made up for by better settling of the precipitated carbonate of lime due to its coarse grain. The lime will pick up some slight impurities from the process and also from the kiln lining, so that it is not possible to burn the same lime over and over indefinitely. Instead of starting with a fresh lot of lime, therefore, it is the general practice to introduce a small quantity of fresh lime into the system at regular intervals. From 5 to 10 per cent is sufficient in most cases. The recovered lime, if burned at all skillfully, will contain fully as much caustic lime as the best lump lime made from limestone. The kiln used for recovering lime waste may also be used to burn lime from limestone provided this latter is crushed to pieces ½ in. and under.

Baltimore, Md.

The Arizona Copper Co. produced during January 1816 tons of copper, some of which was from an accumulation of partly treated material.

Solution Control in Ferric-Chloride Leaching of Sulphide Copper Ores

BY F. N. FLYNN AND ROGER H. HATCHETT

Smelter Superintendent and Smelter Metallurgist of Arizona Copper Co., Ltd.

Determination of Iron and Copper in Chloride Solution

When chalcocite is decomposed by ferric chloride as a solvent, the resulting solution may contain ferrous and ferric iron and cuprous and cupric copper, according to equations (1) and (2) representing theoretical reactions.

(1) $Cu_2S + 2FeCl_3 = 2FeCl_2 + 2CuCl + S$

(2) $Cu_2S + 4FeCl_3 = 4FeCl_2 + 2CuCl_2 + S$

It is apparent from these equations that a comprehensive laboratory investigation of the action of ferric chloride as a leaching agent for sulphide ores of copper, and the subsequent treatment of the resulting liquor, requires that the chemist be able at any stage of the operation to determine in what condition the iron and copper salts exist in the solution.

A scheme for estimating these quantities, and that served as a guide in conducting leaching experiments, was worked out in the laboratory of the Arizona Copper Company, Ltd., Clifton, Ariz. Experiments were not carried far enough to prove that the method gives exact or quantitative results. Details of procedure are given for anyone interested in this work who has no better scheme, and who may have time and apparatus to determine the limits in which the method is trustworthy.

Total Iron

To a measured quantity of the neutral solution to be tested add a little hydrochloric acid. Boil with test lead to precipitate copper and reduce iron. Filter and titrate the iron in the filtrate with a standard solution of potassium permanganate or potassium bichromate as desired, preparing the solution accordingly. This titration gives *total iron* in the solution.

Ferrous and Ferric Iron

To a second measured portion of the cold neutral solution add an excess (2 or 3 grams) of precipitated calcium carbonate and stir vigorously for two or three minutes. Ferrous iron remains in solution, but all the ferric iron is precipitated as ferric hydroxide thus:

$$2FeCl_3 + 3CaCO_3 + 3H_2O = 2Fe(OH)_3 + 3CaCl_2 + 3CO_2$$

Filter and thoroughly wash the precipitated ferric hydroxide. The precipitate and filtrate are separately prepared for titration by reducing the hydrochloric acid solution with test lead, and the iron contents determined by the method used for total iron. The sum of the two titrations giving ferric and ferrous iron should equal the total iron previously found.

The separation of ferric and ferrous iron by precipitation with calcium carbonate and filtering must be done without heating the test. If the neutral solution is made hot, a precipitate usually appears before calcium carbonate is added. And, further, more copper is precipitated from a hot than from a cold solution. The copper thrown out increases the bulk of precipitate and makes it more difficult to filter and wash.

Total Copper

Determine total copper by any reliable method. A rapid scheme is to measure a third portion of original solution and completely oxidize it with potassium chlorate and hydrochloric acid. Neutralize with sodium carbonate, acidify with acetic acid, add two or three grams of sodium phosphate to precipitate iron. Now add three or four grams of potassium iodide and titrate with a standard solution of sodium thiosulphate as in the ordinary titration for copper. This titration gives *total copper*.

Cupric and Cuprous Copper

A fourth measurement of sample is acidified with hydrochloric acid, three or four grams of potassium iodide added, diluted, and the total oxidizing power determined by titrating the liberated iodine with a standard solution of sodium thiosulphate (1 cc = 5 mg Cu, or 4.40 mg Fe). This titration measures the ferric iron and cupric copper together. From the burette reading, subtract the equivalent of ferric iron already determined, and calculate the difference as copper, which is copper present as *cupric chloride*.

Sometimes the end point is not permanent in the thiosulphate titration for iron and copper. To check the result another sample may be measured and the total reducing power determined by titrating in a sulphuric acid solution with a standard solution of potassium permanganate (1 cc = 10 mg Fe, or 11.37 mg Cu). This titration gives cuprous copper and ferrous iron together. The equivalent of ferrous iron already found is deducted from the burette reading and the difference calculated as copper, which is the copper present as *cuprous chloride*.

Known quantities of the purest salts obtainable were weighed and mixed in solution and the results of separating the iron are given in Table I.

TABLE I

Test No.	Milligrams Weighed in Mixture: Fe as $FeCl_3$	Fe as $FeCl_2$	Cu as $CuCl_2$	Cu as CuCl	Milligrams Iron Found by Calcium Carbonate Separation: Ferric in Precipitate	Ferrous in Filtrate
1	125	...	...	...	125	...
2	...	125	...	...	...	125
3	125	125	...	...	125	125
4	125	...	125	...	125	...
5	125	...	...	80	100	25
6	125	...	...	125	80	45
7	125	125	125	...	175	75
8	125	125	...	125	110	140
9	125	125	125	125	112	138
10	...	125	125	...	25	100
11	...	125	...	125	9	116
12	...	125	125	125	14	111

Notes.—When iron salts alone are dealt with, the separation with calcium carbonate can be completed so quickly that oxidation from working in the atmosphere is inappreciable. If either cuprous or cupric salts are added to a solution of iron salts, some copper is usually precipitated with the iron, and filtration becomes retarded, apparently caused by oxychlorides of copper forming. The addition of ammonium chloride helps to make filtration quicker.

Mixtures made of known weights of chlorides of iron and copper show that cupric or cuprous chloride accelerates the oxidation of ferrous to ferric chloride, and cuprous chloride reduces ferric to ferrous chloride. The extent to which such reactions go on in solution in either direction before stable equilibrium of the system is reached is governed in some degree by the relative quantities of these substances present. This, no doubt, explains why weighed quantities of these salts were not recovered in the same condition in which they were mixed.

Arizona Copper Co.,
Clifton, Ariz.

Tropical Agriculture.—The *Proceedings of the Third International Congress of Tropical Agriculture*, held last June in London, have just been published in form of volume of over 400 pages (London: John Bale, Sons and Danielsson, 10s. net). It contains the abstracts of the more than 150 pages presented and reports of the discussions, together with the address of the president, Professor Wyndham R. Dunston.

Notes on the Reverberatory Furnace

BY FRANCIS R. PYNE

Refinery Superintendent U. S. Metals Refining Co.

The reverberatory furnace is an apparatus for smelting ores or melting and refining metals on a suitable hearth. The heat required for this operation is obtained from the combustion of fuel within the furnace proper, the fuel being in the form of oil, powered coal, or gas, the latter being generated in a regular gas producer, or by the incomplete combustion of coal in an adjacent firebox.

The area of the hearth depends upon the size and nature of the charge it is desired to handle, some furnaces carrying a deep bath of small area, others a shallow bath of large area.

The length of the furnace is limited only by the ability to obtain the desired temperature at the uptake end, the width is limited by practical difficulties in building roofs that will stay up. The height depends upon the size of the cold charge and upon having sufficient space for the combustion of the gases.

The character of the hearth, walls and roof is dependent upon the nature of the charge and the temperature desired. An acid charge requires an acid lining, a basic charge requires a basic lining. When the temperature is high very refractory material must be used; with a lower temperature we may use less refractory and consequently less expensive material.

The radiating surface of the reverberatory being large, the heat lost by radiation may reach a considerable figure. Therefore all precautions should be taken to keep this radiation loss as low as possible. A good high-grade refractory is generally a poor insulator and should be backed up by some material which is a good insulator at the temperature of the outside of the refractory. It must be borne in mind, however, that if a refractory is used at a temperature near its softening or melting point, free radiation must be permitted else the refractory will be destroyed rapidly, in some cases even water cooling may have to be resorted to, to preserve it. Many materials which are good insulators at low temperatures lose this property and become good conductors at more elevated temperatures.

The temperature attainable in a reverberatory depends upon the calorific intensity of the products of combustion. Insufficient air to burn the fuel or an insufficient mixing of air and gas keeps down the temperature regardless of the amount of fuel burned; an excess of air has the same effect by diluting the products of combustion, thus lowering the calorific intensity.

In many cases when burning coal in an adjacent firebox attempts are made to cause complete combustion in the firebox. This causes an exceedingly high temperature locally which rapidly decreases towards the flue end of the furnace. The result is an inefficient furnace and frequent burnings out of the firebox. The fire should be handled so as to produce a large volume of combustible gases which are then completely burned in the furnace by admitting the required air. The grate area is, properly speaking, not a function of the hearth area but of the volume of the furnace; a grate that will have a satisfactory area for one furnace will not give satisfaction if the roof of the same furnace is raised several feet.

It should be borne in mind that the largest part of the heating is by radiation from the hot gases and not by actual contact. In the very short space of time taken by the gases to pass through the furnace only a very small part is in actual contact with the charge while the whole volume of the flame is radiating heat to the hearth, walls and roof.

In order for a reverberatory to properly perform its functions, its hearth, walls and roof must be heated up to or above a certain critical temperature. This temperature depends entirely upon the nature of the material being treated, and unless this temperature is attained no results are forthcoming. In an ore smelting furnace a temperature of say 2100° F. is required. If the furnace is so designed or the grade of coal is such that the highest temperature attainable is but 2000° F., nothing will occur save maintaining a large body of ore at 2000° F., no matter how much fuel is burned. And as one fuel gives so many hundred degrees more temperature than another, so is the first worth much more than the second.

Where a reverberatory furnace is used for melting and refining, it performs two separate and distinct operations. During the melting down period it furnishes sufficient heat to melt the charge and to make up for the losses by radiation. During the refining period it merely takes care of the radiation losses. Now all of this heat must be supplied at a certain definite temperature, so that if a furnace has but one source of heat supply, namely, one firebox, one gas port, or one oil burner, it is readily seen that if the furnace gets just sufficient heat from this source for melting, it will receive an excess of heat when merely keeping the metal molten by making up for the radiation losses, and any decrease in the rate of combustion will cause a lowering of the temperature. This indicates the desirability of having a plurality of sources of heat supply so that the temperature may be held constant while the amount

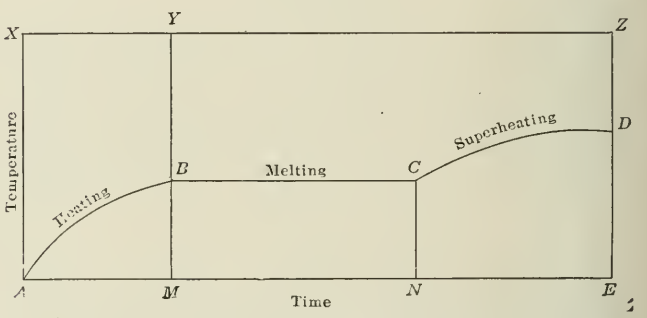


FIG. 1—THE TIME FACTOR IN REVERBERATORY SMELTING

of heat units is decreased to the desired point. This is not practicable with the coal fired furnaces, but can be applied to furnaces using oil, gas or pulverized coal.

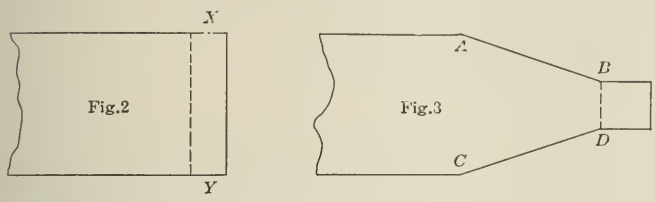
For rapidity of melting it is necessary that the furnace be designed to produce a temperature well above the melting point of the charge. The time factor may be illustrated by Fig. 1. Let XZ represent the furnace temperature. Now a charge of metal at temperature A will be gradually heated to the melting point B in time AM, at B the latent heat of fusion BC is absorbed during the time MN, at C the superheating begins and proceeds as per the line CD in time NO.

The amount of fuel burned is proportional to AO and if this can be decreased the result will be more available melting time for the furnaces. From A to B the heat absorption is rapid under the temperature head AX, but gradually decreasing as it approaches B where the head is only BY and at the point D it is still slower, the head being reduced to DZ. Now in order to reduce the time AO we must increase the temperature head AX, requiring a more rapid combustion of fuel. The attainable temperature is limited by the nature of the fuel and the material of the furnaces, but as long as the extra fuel consumption to increase AX plus the extra furnace repairs does not exceed the saving in time and labor, the furnace will be more economical when working at the higher temperature.

Many reverberatory furnaces do not work to satisfaction because proper attention is not given to the construction of the flue end. This results in the furnace being cold at this point, while the fire end may be over-heated.

If the flue end is square as at *X* and *Y* (Fig. 2), the metal will tend to chill in these corners, due to the great radiating surface presented. By making the end tapered as *AB*, *CD* (Fig. 3), this radiating surface is lessened and the metal kept hotter. The sides *AB* and *CD* should be well backed up with a good insulator to further decrease radiation. The amount of taper depends on the available space that can be given the furnace, but in all cases it is desirable to extend it as far as practicable without unduly reducing the capacity of the furnace.

There is another reason for the reduction in volume of the flue end. As the gases pass through the furnace they drop in temperature, thereby decreasing in volume.



FIGS. 2 AND 3—CONSTRUCTION OF FLUE END OF REVERBERATORY FURNACE

If the volume of the furnace remains constant for all sections, the velocity of the gases decreases as they become cooler. Heat is being continually lost by radiation, the velocity continues to decrease and in consequence the furnace begins to build up at the flue end as the metal cools. To prevent this more fuel must be burned, causing the furnace to become overheated at the fire end and increasing the fuel cost per ton of metal. An ideal furnace would have the combustion take place gradually throughout its length, thereby keeping all parts at the same temperature, but this ideal furnace does not yet exist in practice. Therefore, in order that the velocity may be kept sufficiently high to prevent this cooling the volume of the furnace must be reduced, and this is done by tapering the sides and lowering the roof.

That part of the roof which is lowered is called the hood and besides aiding to reduce the volume of the furnace and maintaining the velocity of the gases, it throws the heat down on the metal where it tends to be coolest, and this is an important point in keeping the flue end at the proper temperature. The height above the bath of the point where the hood joins the flue is a factor which varies under different conditions. A few inches one way or the other makes a great difference in the working of the furnace and can only be determined by experiment.

The question of draft enters largely into the working of a reverberatory furnace. Unless the draft is strong enough to give proper combustion the furnace will be run very uneconomically. Sufficient draft should be furnished so that there is always a good pull on the gases passing through the furnace, otherwise the furnace will not "clear" and give a good, sharp cutting flame which is the kind needed for melting.

With coal-fired furnaces forced draft is often used, but in such cases the forced draft should be carefully regulated and never permitted to reach such a degree that there is a pressure inside the furnace. When this condition exists flame may be seen coming through any crevices in the walls and roof, the furnace will not "clear" properly and the fuel consumption is increased.

If the furnace has waste heat boilers or other devices for utilizing waste heat, sufficient draft must be allowed for to take care of the increased resistance as the tubes become dust coated, a small amount of dust on the boiler tubes and flue having a marked effect upon the passage of the gas.

Chrome, N. J.

The Extraction of Carbolic Acid from Oils of the Distillation of Coal Tar

BY WILLIAM MASON

The method, used in many works for the extraction of carbolic acid, has been to treat the oils with a solution of caustic soda; in this way a sodium phenate solution is formed and separated from the oils. This sodium phenate is then decomposed by sulphuric acid. By this method, it is easily seen, the whole of the caustic soda and sulphuric acid are lost, which materials cost, at least 8d. (16 cents) to extract 1 gal. of carbolic acid.

The cheapest and best method is to treat the light oil with caustic soda solution of about 1110 sp. gr. whereby a sodium phenate is produced which may be separated from the light oil from which it has been extracted by subsidence. This sodium phenate solution is then treated with a current of carbonic-acid gas which forms sodium carbonate, and sets the carbolic acid free. The separated carbolic acid floats on the surface of the strong sodium carbonate solution which is drawn off from below the carbolic acid, and, being causticized with lime, is employed over again continuously.

The point, however, to be considered in this method is the production and purification of the carbonic acid. This gas may be produced in a coke furnace; but much care would have to be exercised in its construction and operation, since to obtain gases containing much carbonic acid would result in a higher temperature being obtained than the materials of the furnace would with-

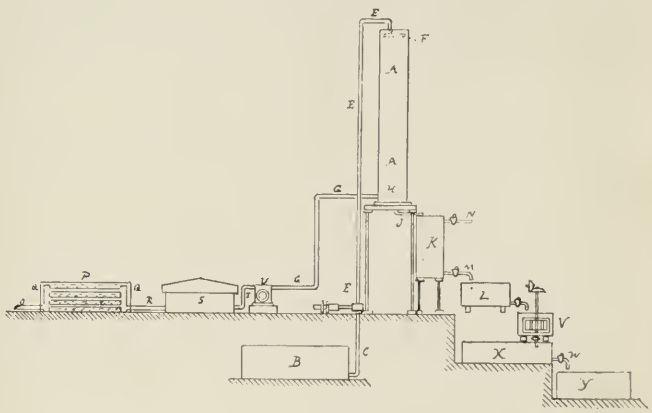


FIG. 1—THE EXTRACTION OF CARBOLIC ACID FROM OILS OF THE DISTILLATION OF COAL TAR

stand. With escaping gases containing only 6 per cent of carbonic acid, the initial temperature would be about 900 deg. C. These gases, too, would have to be purified and cooled.

Now, since tar and ammoniacal liquor are generally distilled in the same works, carbonic-acid gas may be obtained from the waste gases issuing from the sulphate of ammonia saturator. A typical gas liquor contains per 100 parts of liquor: 2.5 parts of NH_3 = 10 of $(NH_4)_2SO_4$; 0.5 of H_2S; 2.3 lb. of CO_2; or 10 lb. of sulphate of ammonia, 0.5 lb. H_2S; 2.3 lb. of CO_2, or 5.26 cu. ft. of H_2S and 18.7 cu. ft. of CO_2 (at 0 deg. C. and 760 mm) per 10 gal. Whence 1 ton of sulphate of ammonia would yield $5.26 \times 224 = 1180$ cu. ft. of H_2S and

18.70 × 224 would yield 4190 cu. ft. of CO_2, or a total quantity of 5370 cu. ft. of gas, and such a mixture would contain of CO_2 78 vol., and of H_2S 22 vol. per 100 vol. From these figures it is evident then, that in most works of this description there is much carbonic acid which might easily be utilized.

As the author has had practical experience with this method he will describe it by the accompanying drawing: *A* is a tower which is packed with stone, coke, or other similar materials, or provided with shelves of any suitable metal. *B* is a tank to which is supplied a solution of alkaline phenate, or cresylate obtained in the usual way. A pipe *C* connects the interior of the tank *B* to a pump *D* which is connected by means of a pipe *E* with perforations. The solution of alkaline phenate or cresylate is pumped from the tank *B* along the pipes *C* and *E* and escaping from the perforations formed in the pipes *F* flows slowly down the interior of the tower *A*. While flowing down the solution meets with the ascending carbonic-acid gas which is conducted to the base of the tower *A* by the pipe *G*, terminating within the base of the tower in pipe *H* provided with perforations through which the carbonic-acid gas escapes. The descending solution of sodium phenate or cresylate by being acted upon by the ascending carbonic acid gas is caused to become a mixture of sodium carbonate and carbolic acid. The mixed liquids on reaching the base of the tower *A* flow through the pipes *J* into a deep dividing or separating tank *K*, from which the sodium carbonate, as it separates from the carbolic acid, is run out by means of pipe *M*, fitted with a tap on the bottom of the tank, into a tank *L*, while the carbolic acid is run off by a pipe *N*, also fitted with a tap and near the top of the tank *K*. This carbolic acid is then made acid by sulphuric acid.

The carbonic acid used in this process is obtained from the waste gases in the manufacture of sulphate of ammonia from ammoniacal liquor which are conducted by means of a pipe *O* to a series of pipes *P* situated in a tank *Q* which contains water by which the pipes *P* are surrounded. Cold water is supplied to the tank *Q* in any suitable manner. By passing the waste gases formed in the manufacture of sulphate of ammonia from ammoniacal liquor through the pipes *P* nearly all the vapor of water and tarry matter are condensed and separated from the gases. The gases are then conducted from the pipes *P* by a pipe *R* to a purifier *S* which contains oxide of iron, similar to those used in the manufacture of coal gas and in this the sulphuretted hydrogen contained in the gases is extracted, and the remaining almost pure carbonic acid gas is conducted from the purifier by a pipe *T* to a pump *U* actuated in any suitable manner, by which the carbonic-acid gas is supplied through the pipe *G* to the perforated pipe *H* at the bottom of the tower *A*.

The above-mentioned sodium-carbonate solution is conducted into an agitator *V* of any suitable shape where it is causticised with lime, and after it has been so treated it is run therefrom by means of the pipe *W*, which is provided with a tap, into a settling tank *X*, in which the lime is separated. The solution is then run into the tank *Y* and contains from 2 to 3 per cent of caustic soda, and is of a suitable strength to treat a fresh quantity of tar oils. In this manner the process is made continuous.

This process has several advantages over the ordinary process for obtaining carbolic or cresylic acid in which sulphuric acid is employed: namely, no sulphuric is used; about 90 per cent of the caustic soda is recovered; also the liquor is utilized which in the ordinary process was difficult to dispose of, being a source of nuisance by polluting river streams and other waste courses.

Finally, there is one other matter which requires attention, and that is the condensed water from the coolers contains hydrogen sulphide in solution, which has to be dealt with before it leaves the works. In one works with which the author had experience it was allowed to run away into a sandy soil, and was thus got rid of. A much better method would be to dehydrate the gases as is done in the ammonia soda process, by placing a surface cooling coil between the still and the saturator at such an altitude that the condensed liquor could be syphoned back into the still, or the coil may be placed on the ground, and the condensed liquor collected in a closed vessel, may be pumped back into the still. In this way the gases issuing from the saturator would consist only of carbonic acid and hydrogen sulphide, and would, therefore, not require the large scrubbers and condensers usually employed for this purpose; besides, nearly the whole of the sulphur might be recovered in the purifier, and in works where carbonic acid is already being used, only inexpensive additions would be required, and the operations might be much quickened by using nearly pure carbonic acid.

Oxford, England.

The Non-Ferrous Metal Market

The trend of non-ferrous metal prices during April was distinctly upward. Copper was remarkably stronger and transactions were in fairly large quantities. Lead prices ranged higher early in the month, but fell off later owing to reduced export demand. Tin was the most erratic and fluctuated widely. Spelter continued at a high price in spite of a fairly large business.

Copper.—The market for this metal reached 16 cents on April 12, and ranged as high as 16.20@16.35. Domestic demand continued heavy, and as the statistical position is regarded as strong, prices are likely to range high.

Tin.—Since our last report the price for this metal has gone as high as 56@58 cents per pound, fluctuating widely on small transactions. Comparatively small business is being done. At last reports the market was unsteady at 55 cents.

Lead.—Exports of this metal continue to show an increase. The American Smelting & Refining Co. advanced the price to 4.20 cents, New York, on April 1, since which time it has remained at that point. St. Louis prices have been above the New York parity, owing to buying for export, but have again receded to 4.10@4.15 cents.

Spelter.—The unusual situation in this market continues, and prices are higher than a month ago. More buying has been done by domestic galvanizers. Spot metal continues to command a premium, while future deliveries are available at prices below the current quotations. About the middle of April New York spelter was quoted at 8.92½@9.67½ cents; St. St. Louis, 8.75@9.50.

Other Metals.—Aluminium has been quiet, with prices steady at 18¾@19 cents per pound. Business in antimony is quiet, owing to scarcity of supply. Prices range widely, according to brand, from 25 to 32 cents per pound. Quicksilver is unsettled. Prices have been as high as $67 per flask of 75 lb., New York, but about April 15 the metal was to be had at $62. San Francisco price was $64.50@$65.

A **welding flux** or compound patented by W. W. Hout, of Cortland, N. Y., contains boracic acid, iron or steel particles, furnace dross and calcined marble dust.

A Case for Copper Hydrometallurgy

Inexpensive and Efficient Treatment of Smelter Flue Dust and Carbonate Ore

BY GEORGE C. WESTBY

A small leaching plant of a Western copper smelter is an illustration of an adaptation of peculiar conditions to reduction of cost in the treatment of flue dust and incidentally of carbonate ores.

The flue dust which had been withdrawn from the flues in cleaning had weathered for a considerable period and contained much free sulphuric acid and soluble sulphates of copper and iron.

The former method of treatment had been to charge the flue dust into reverberatories and smelt it with the regular charges of calcined ore. There was a consequent cost for handling and serious loss through furnace draft and boiling due to the fine state of division of the material and the presence of sulphates, acid and moisture.

A former superintendent of the plant decided, in view of the composition of the flue dust, that a wet method of treatment might be devised that would be cheaper than charging the material to the furnaces, and he initiated the investigation of the problem.

The principal difficulty to be met consisted in the fact that the whole arrangement to be used in the treatment of the material must cost but little, since the quantity of flue dust available for treatment was limited and the current production hardly more than 5 tons per day. The other factors of the problem, such as the solubility of the copper, were all in our favor.

Results from Experimental Plant

To get a logical starting point and necessary data for estimates and design of plant, equipment having a capacity of about 1 ton in eight hours was put in operation. This plant consisted of a heap of flue dust, a few barrels filled with carbonate ore and fitted with filter bottoms, a flume 16 in. by 8 in. in cross section and 100 ft. long, a small Pachuca agitator, a settling launder and a series of barrels filled with iron. The plant was operated by means of a stream of water into which a laborer shoveled the flue dust as the water flowed through the launder. After agitation and settlement the solution passed successively through the carbonate ore and precipitation boxes.

The information gathered from a short trial of the experimental plant showed that the flue dust could be rapidly disposed of by a comparatively small plant, without material modification of the general arrangement tried on an experimental scale. The test established also the commercial feasibility of the scheme.

It was determined to be practicable, in view of the rapid sedimentation in the settling launder, to make the process continuous. This, however, would have necessitated the preparation of a much larger oxidized-ore yard, the inconvenience of night work and larger or longer precipitation boxes, all of which would not be warranted by the limiting conditions. Settling capacity would not have been difficult to secure as earthen settling ponds might be used.

Intermittent Process Adopted

An intermittent process was adopted and a plant designed to treat profitably about 25 tons of flue dust and carbonate ore per day. The design embraced about 400 ft. of 9-in. by 9-in. tarred wooden launder, about 500 ft. of 6-in. tarred paper conduit pipes, two earthen settling ponds or settling tanks, a heap of oxidized ore and 300 ft. of 3-ft. by 3-ft. precipitation boxes.

The wooden launder was to be so arranged that its upper lengths could be moved laterally toward the flue-dust piles as clearance was made by shoveling the material into the launder. The design called for the direct treatment of flue dust as drawn from the flue hoppers by placing the settlers sufficiently below the elevation of the hopper bottoms so that the contents of a hopper could be dropped into a launder and sluiced to the settlers. It was shown that in this manner a concentration of the insoluble values could be effected, the soluble salts and acid effectually removed and the concentrated residue easily sluiced where it could drain and later be easily handled.

The estimated cost of production per pound of copper from the flue dust was as follows:

	Cents per pound
Amortization	1.0
Iron for precipitation	2.0
Labor	0.5
Supervision, laboratory and repairs	0.5
Preliminary and experimental work	1.0
Freight, refining and selling	2.5
Total	7.5

The estimated cost of the plant was between $1000 and $1200.

The exigencies of practice suggested various changes of the general plan as laid out, but the only radical innovation consisted in dispensing with the shovelers and

FIG. 1—SLUICING FLUE DUST

simply sluicing the flue dust from the heaps directly into the launders or conveying pipes in imitation of placer work.

Hydraulic Sluicing of Flue Dust

A stream of water from a 2½-in. hose under 60-lb. pressure was directed through a nozzle to the flue-dust pile. The heap was rapidly disintegrated and washed into an earthen basin in which the heavier particles settled. The current carrying the flue dust then flowed through a short, broken, rocky channel to a 9-in. by 9-in. launder, the sections of which were arranged in steps in order to cause a cascading of the mixture and thorough agitation of the flue dust and water, and secondarily to break up cemented lumps of flue dust by the consequent impact. The launder was about 400 ft. long and emptied into the settlers which consisted of two Arizona tanks 28 ft. by 14 ft. by 10 ft. (substituted for the ponds first proposed). The soluble constituents of the flue dust were completely extracted before reaching the end of the launder. The Arizona tanks were usually filled in about three hours, and the sediment allowed to settle out of the solution over night.

In the morning the solution was pumped out of the tanks by means of adjustable air lifts and caused to flow into the carbonate-ore ponds. The solution was robbed of the greater part of its acid content as it gradually percolated through the ore pile to the asphalt floor beneath.

The plant was located close to a spur track, along which the carbonate-ore yard and the precipitation boxes were laid out.

Construction of Carbonate-Ore Ponds

The ore yard was formed by clearing a space of sloping ground about 80 ft. long by 70 ft. wide. The prepared ground was covered with a rough surface of broken brick, over which was spread a very argillaceous slime brought from concentrator. After drying a coat of Portland cement was brushed over the hardened clay. The yard was then completed by melting over it three coats of asphalt. The asphalting was extended almost to the top of the railroad embankment.

On this prepared floor was spread a 6-in. layer of ore, the irregular fragments of which averaged in their smallest dimension about 3 in. On this was piled about 1500 tons of ore, 9.4 per cent of which remained on a ½-in. mesh screen and 53.4 per cent passed through a ten-mesh screen. The ore was dropped over the embankment from self-dumping ore cars, distributed later by means of a steam crane and finished by a scraper to form a flat top surrounded by low walls, thus making a rough basin to retain the acid liquor charged on the ore from the settlers.

The drainage from the ore pile flowed into a small sump and this discharged into the precipitation boxes. The sump was set low enough so that any possible leak through the asphalt floor would flow along the ground through the interstices of the broken brick and finally discharge to the sump.

The carbonate ore was usually leached to a white residue in from five to six weeks. No channeling of any consequence took place, but the walls of the pile were acted on more slowly by the solutions and were usually left in place when the rest of the material was removed. A continuous percolation through the sides occurred, but this showed only in dry weather by the accumulation of crystals of cupric and ferric sulphates on the outer slopes of the walls.

On completion of the leaching and the subsequent washing, the residue was excavated by a steam crane, to the extent of its reach, and dropped on the other side of the railroad track. The remainder of the material was sluiced through gates built into the walls of the pile. The time required to clean the floor of the yard was ordinarily about twenty-four hours. To fill with fresh ore, level and prepare the top of the pile for a pond required from sixteen to twenty-four hours.

Precipitation of Copper from Solution

The strength of the solution draining from the ore pile changed slowly, but varied at different times between 0.5 per cent and 4 per cent, as the copper and acid tenor of the flue dust and wash solutions varied and the copper in the ore pile decreased. The copper in the discharged precipitated solutions remained constant at about 0.01 per cent. The discharge was controlled by leaving iron out of the precipitation launder or by increasing the quantity of iron introduced, and regulating the temperature of the solution by means of steam jets near the head boxes.

A single flume, 3 ft. by 3 ft. in cross section and 300 ft. long, was used for precipitation of copper. At intervals along the flume bulkheads were placed to maintain the solution at or near an average level of 33 in. above the bottom of the flume. The iron with which it was charged was dropped over the embankment of the railroad track from a small flatcar on which the iron had been collected from different parts of the smelter grounds.

An arrangement which saved much time by obviating the removal of the iron, consisted in the insertion of barrel staves spaced along a stringer, placed longitudinally from cross braces on the flume. A longitudinal space 7 in. wide was left along one side of the partition formed, in order to provide an opening for the shovels used in removing the precipitate. The iron was charged into the bellied side of the partition; and the precipitated copper, much of which was pulverulent, was gradually discharged through the interstices of the partition to the small compartment where it accumulated until the box was cleaned. It is obvious that this arrangement could be modified so that the precipitate could be removed from both sides of the flume; and that deflection wings, or the use of air or steam jets, or mechanical stirring would materially accelerate the precipitation of copper by inducing rapid circulation of the copper-bearing liquor through the iron.

General Results

Two men operated the plant. At set intervals during the eight-hour day they sluiced the flue dust into launders; made connections, repairs and extensions of the system; collected cement copper; supplied fresh scrap iron to the boxes where needed; and every second day

FIG. 2—SLUICING FLUE DUST

1—Tarred conduit pipe. 2—Washing flue dust out of broken brick and mortar. 3—Earthen dam.

washed and sluiced out sediment which had settled in the tanks.

The general results obtained may be fairly illustrated by data secured on one experimental batch consisting of 248 tons of flue dust and 250 tons of carbonate ore. The summary is as follows:

1	Total copper in material, pounds	19,073
2	Copper left in residue as sulphide, and soluble copper lost in sediment after washes, pounds	729
3	Copper lost in discharge from precipitation launders, pounds	200
4	Copper lost in leaks from pile, pounds	60
5	Copper lost in leaks in precipitation launders, pounds	78
6	Total copper recovered, pounds	18,006
7	Percentage recovery	94.4

Item 3 was higher than the general average loss at the discharge.

Item 4 was determined by difference, roughly checked by measurements.

Item 5 was deduced by weighing crystals scraped from the boxes and by measuring and estimating as closely as possible the tiny leaks which appeared from time to time.

Summed up the treatment described was a successful solution of a minor smelter problem, in which some of the beneficent elements of fortune were with us. Further than this, the plant lent encouragement and provided means to make experiments on the wet treatment of mill and smelter products and ores—systematic

experiments tried on a sufficiently large scale to provide really useful data applicable in future operations. Altogether the case is cited as one in which the theory and practice of copper hydrometallurgy worked together without dissention.

Ludwig, Nevada.

Industrial Motor Applications

Some Considerations Affecting the Choice of Motor and Auxiliary Equipment in the Metallurgical and Chemical Industries

BY H. B. BARNES

In undertaking the following analysis of some of the considerations entering into the broad field covered by the above title, it is not the intention of the writer to enter into the theoretical side of the problem, but rather to present in a non-technical way such information as will enable the mining or metallurgical engineer to analyze his problems; or to more intelligently review the analysis and conclusions of others as they affect his particular conditions. It is a fact that many of the technical men in charge of present day industries are men who secured their training years ago, and to whom much of the recent development of electrical machinery is unfamiliar. There is also the large class of the younger men, recent graduates of technical schools, who have not yet had an opportunity to gain through experience the familiarity with electrical equipment, and the practical considerations in connection with its use, that are necessary for its intelligent application. To such engineers it is hoped that this article may prove of interest and perhaps of value.

Choice of Systems

The average user of electric power is a consumer only, seldom a producer, and therefore the choice of the system to be used is usually made for him, as he has to use what his local power company will furnish. However, there are many cases, especially when local conditions compel the installation of an isolated plant, where the choice of the distribution system to be used must be carefully considered. Such a choice involves a study of the individual problem which can hardly be expected from one unfamiliar with the considerations involved, and it should properly be placed in the hands of a competent consulting engineer.

For reasons of efficiency, economy in transmission, etc., the use of polyphase alternating current has become well-nigh universal in this country, and practically all electric service companies supply energy in this form. The user's problem thus becomes the selection of alternating-current motors to meet his conditions, or of direct-current motors with proper characteristics, and of such transforming apparatus as may be necessary for converting the purchased energy from alternating into direct current.

In many installations made years ago, direct-current motors are still used in large numbers, but the later equipment and the equipment of nearly all new enterprises is almost invariably designed for alternating current, and for this reason the following article will deal only with alternating-current motors and their applications.

Motor Characteristics

The polyphase induction motor, either two or three-phase, has certain operating characteristics that are seldom clearly understood, either in their relation to the work to be performed or in their relation to each other, and yet it is only by a complete understanding of these characteristics that an intelligent selection can be made to meet certain predetermined conditions.

The familiar induction motor of the so-called "squirrel-cage" type is ideal in its simplicity of construction and operation due to its freedom from brushes, moving wires, and from all wearing parts except the bearings, which are usually made dust-proof and with automatic ring-oilers which require a minimum amount of attention. The construction of this apparently simple squirrel-cage rotor, as the revolving member is termed, has a vital bearing on the service to be rendered by the motor for the following reasons:

1—The starting torque of a squirrel-cage motor, for a given applied voltage is approximately inversely proportional to its rotor resistance.

2—The full-load running efficiency of the same motor is also an inverse function of its rotor resistance.

It is thus obvious that the construction required to produce maximum starting torque is the identical construction that produces the worst running characteristics, so that it becomes necessary to compromise or to eliminate these opposing tendencies. Assuming that a certain rotor resistance gives maximum running efficiency and the best regulation, approximately eight times this resistance is required to produce maximum starting torque in the same motor. This problem has given rise to several different forms of rotor construction. The familiar squirrel-cage rotor with low-resistance end rings is the standard construction for motors designed for starting under relatively light loads or where the load can be thrown on after the motor is up to speed, and this is the type of motor most generally used.

For intermittent operation where high starting torque is required and close speed regulation is not essential, such as in elevator work, the squirrel-cage motor with high-resistance rotor is frequently used on account of the simplicity of its control, and there are conditions, as for instance where long line-shafts have to be started, where slight increases are made in the rotor resistance, the purchaser being willing to sacrifice a few per cent in efficiency to obtain greater starting torque, on the score of greater simplicity and reliability in his motor equipment. This "high-resistance rotor" type of motor has been standardized by several manufacturers and under certain conditions has proved a very satisfactory machine.

For constant-speed work where high starting torque is required, several methods have been developed by different manufacturers for inserting the necessary resistance into the rotor circuits during the starting period, this resistance being short circuited or cut out when the motor is up to speed, thus giving the motor the ideal running characteristics. In every case such a motor is provided with a so-called "phase-wound" rotor, the distinction being made between the form-wound coils and polar arrangement used in this construction, and the straight bars and end rings used in the "squirrel-cage" type. One manufacturer provides a centrifugal device in the body of the rotor which automatically short circuits the rotor winding when the motor approaches full speed; another provides a hand-operated device for cutting out an internal resistance, up to certain motor sizes, while all manufacturers have standardized the so-called "slip-ring" type of motor in which the terminals of the rotor winding are brought to collector rings on the shaft, through which rings any resistance combination desired may be introduced into the rotor circuits by means of external resistors and switching devices.

The so-called "synchronous" motor, which normally operates at all times in exact synchronism with the generator supplying its energy, has a relatively limited application. It is essentially a light-load starting machine, but under certain conditions is extremely val-

uable on account of the corrective characteristics which it exercises on the line and equipment used in conjunction with it. These characteristics are of an extremely technical nature, and as they are of interest chiefly to the company supplying the power, they need hardly be considered here.

There are also several commutator-type motors, both single-phase and polyphase, which have been recently put on the market, which have operating characteristics approximating those of direct-current motors. They have not come into very general use except in the smaller sizes and have only a limited application.

Character of Service

In most commercial power applications the motor service naturally falls into one of the following classes:

1—Constant speed, light starting loads.
2—Constant speed, heavy starting loads.
3—Intermittent service.
4—Variable speed.

The choice of motors for operation in any of these classes depends not only on the service to be rendered and the operating characteristics of the motor, but also on the source of power supply. Obviously a power system having several thousand kilowatts of generating capacity behind it is better able to absorb the disturbances incident to the starting of heavy loads than one of only a few hundred. Therefore the operator of a relatively small isolated plant must consider very carefully the size and type of motors he proposes to install, while the purchaser of power from a large system has few if any such restrictions.

Here again the choice between individual motors and group-drive often influences the decision, as the ability to start loads consisting of large groups of machines may often permit substantial economies through concentration of motive power into larger units.

The operation of rolls, crushers, tube-mills, concentrators and accessory equipment as used in modern milling plants is a specific instance of group-drive practice which may justify a brief digression and more detailed analysis. The ideal arrangement is to so group the machines that operate together, that they may be driven by one motor, or at least may be simultaneously controlled. Recent practice favors individual drive for certain machines, notably tube-mills. This has been directly influenced by the developments in the design and commercial production of the "herring-bone" gear which has made possible gear ratios for such work that were impractical heretofore, and have made possible the direct-geared connection of standard moderate speed motors. Individual drive is not, however, to be universally recommended as an analysis of the operating characteristics of such machines will show.

No matter what the mechanical equipment of a mill may comprise, the motor equipment must be proportioned so that it can successfully start any individual part of the plant under the most unfavorable conditions that may arise in service. As a typical case may be taken a crushing or sampling plant consisting of Blake or Dodge type of crusher, one or more sets of rolls, and auxiliaries. Such a plant should properly be driven by one motor, a conclusion that is almost obvious, as a moment's consideration of the requirements of the individual machines will show. The crusher, for instance, may require only 15 to 25 H. P. to run it, but may easily require 50 to 60 H.P. to start and accelerate it. Likewise the rolls which may ordinarily use 10 to 30 H.P., may, if slightly choked, take two or three times this amount to start. Under such conditions the ability to concentrate the motive power of the entire group upon the one refractory unit is of the greatest advantage, and is usually to be encouraged. When the total capacity of a plant is large and is made up of a number of similar units, as in some of the large reduction plants now running, the trend towards individual drive has been very marked, but it is not to be carried to extremes.

In small plants good practice seldom allows the installation of an individual motor of a size greater than 20 per cent of the generator capacity. Thus in an installation having a generator capacity of 250 H.P. a motor larger than 50 H.P. might be expected to cause objectionable disturbances all over the system due to the heavy currents required by such a motor during starting and acceleration, particularly if the motor is of the squirrel-cage type.

A squirrel-cage motor of almost any standard make may be expected to exert a starting torque of about two and one-half times its rated full-load running torque if full line voltage is applied at the motor terminals. Under these conditions, however, it may draw from the line a momentary current from seven to nine times its normal full-load requirements. As the resulting start under such conditions is so abrupt as to be objectionable and the sudden draft of current is frequently so great as to cause disturbances elsewhere on the system, it is customary, except on motors of 5 H.P. or less, to provide a "compensator" or other starting device which reduces the voltage applied to the motor during the starting period. As the starting torque of an induction motor is proportional to the square of the applied voltage, it can be shown that with a motor having a maximum torque at full voltage of 250 per cent of its normal running torque, such a motor will exert a starting torque of 100 per cent of its rating with 63 per cent of normal voltage applied at its terminals. Under this condition the momentary starting current will be limited to from two to two and one-half times the normal full-load requirement of the motor, an amount which is seldom objectionable on any well-designed distribution system.

The starting characteristics of a motor with a "phase-wound" rotor are very different. The performance curve of a typical motor of this type shows that with full-line voltage applied at the motor terminals it will exert a torque equal to 150 per cent of its rating, with a current requirement of only 150 per cent of its normal full-load amperage. The same motor will exert a maximum torque of 200 per cent to 250 per cent of its rating with a maximum current requirement of not over two and one-half times normal. Thus it will be seen that such a motor can start its rated load with vastly less disturbance to the system than can the squirrel-cage type, and also that it can develop a maximum torque condition with hardly more current than is required by the squirrel-cage type to produce normal torque.

For constant-speed work, therefore, the user must consider the size and the nature of the load and particularly the starting conditions, and also the ability of his supply system to absorb the disturbances caused by starting loads, before he can intelligently determine the type of motor to be used for each specific installation.

Intermittent service has two general classes: (1) such as elevator service where the load factor is extremely low and where the load conditions are fairly constant, and where speed variation is not required, and (2) hoist service where the work may be fairly continuous but varying constantly both as to direction and as to loads handled. Accurate speed-control is also essential and the motor may frequently be called upon to operate at reduced speed for considerable periods.

There is also an additional class of intermittent serv-

ice covering automatically controlled pumps for mine or other service.

The "high-resistance rotor" type of squirrel-cage motor, as stated above, has obtained a wide application in elevator service on account of the extreme simplicity of its control, a simple reversing switch being all that is required. A solenoid-operated mechanical brake is usually used with it, connected in series with the motor, the initial rush of current at starting being unusually effective in securing a prompt release of the brake. This type of motor also possesses electrical braking characteristics which prevent overspeeding in lowering, which will be considered more in detail later.

For hoist service the "phase-wound rotor" with slip rings is used exclusively except in the very largest hoists, where various complex systems involving the use of heavy flywheels and other devices for equalizing the load have been found commercially practicable. The three-phase "slip-ring" motor with either hand- or master-control meets fully all the requirements of the most difficult hoisting problems and such motors up to 750 H.P. are in successful every-day operation. In the smaller sizes, say up to 150 H.P., hand-control is the rule, reversing controllers with from five to as high as fifteen speeds being standard apparatus. Such equipments make possible an accuracy of control that is not approached by any but the largest steam hoists, and there is an assurance as to results from handling such a controller that the operator of a steam throttle never gets.

Another valuable characteristic of the polyphase motor for this work is the resistance offered by the motor, when connected to the line, to any tendency to overspeed it, as mentioned above. In operating a single-drum hoist, or a double-drum when unbalanced, substantial savings can be made by lowering with the motor connected to the line; both through recovery of power by the motor acting as a generator, and also by the reduction of wear on the hoist brakes, as the motor will hold the speed constant while lowering and the brakes need be used only to do the final slowing down and stopping.

For the operation of either centrifugal or plunger pumps, especially where automatic or remote control is to be used, the slip-ring motor will be found especially valuable. Automatic control usually involves the acceleration not only of the pump and its motor, but also of a column of water under conditions where any sudden shocks might be disastrous; and under these conditions the slow and uniform acceleration possible with this type of motor is most desirable. The writer was one of the first to recommend and to install phase-wound motors for this class of service, nearly ten years ago, since which time many important installations have been similarly equipped; although it is well known that for high-speed service, where bypassing or other hand-control is possible, the squirrel-cage motor may be preferable under certain conditions.

Variable Speed

The polyphase induction motor is essentially a constant-speed machine. While certain types having phase-wound rotors may be operated at reduced speeds and give very satisfactory service under such conditions, yet their efficiency at reduced speeds and under load conditions requiring constant torque, such as air-compressor or hoist operation, is so low as to make them commercially impracticable. This is due to the fact that the energy dissipated as heat in the resistance, which must be inserted into the rotor circuits to obtain reduced speeds, represents a large part of the total energy supplied to the motor; and as the mechanical output of the motor at reduced speeds is also lowered while the electrical input remains practically constant for a given torque, obviously the overall efficiency of the combination is low. Under certain conditions of load, as for instance mine-fan operation, where the torque required decreases with a decrease in speed, this type of motor will show a decreased power consumption at reduced speed; but it is still so inefficient that it is seldom if ever used alone for such service. In the large sizes the energy otherwise dissipated in the resistors is sometimes recovered and returned to the line through so-called "regulating sets," but as these auxiliaries are large and expensive in proportion to the economies effected they are not commercially practicable, except as before stated in the larger sizes, say 300 H.P. and above.

Single and polyphase motors of the "repulsion" type have been developed in the smaller sizes which give fair speed-control and regulation over a limited range and with good efficiency. Such a motor has a commutator and brushes, the speed variations being obtained by shifting of the brush holder, or by means of external controlling devices. Due to the construction, complex as compared with the squirrel-cage motor, they are almost invariably heavier and more expensive than the constant-speed types, so that where variable speed is required it is usually cheaper and more satisfactory to obtain it by some mechanical means.

Multi-speed motors. As distinguished from variable-speed motors there is an established type of induction motor which has two, or in some cases three fixed operating speeds at any one of which it will develop its full rated torque, although of course with output reduced in proportion to the speed. In the case of the two-speed motor these are usually full and half speed, which speed change is obtained by means of a simple double-throw switch which changes the number of poles for which the primary winding is connected. Other speed changes and ratios are obtainable in the same way, but the complication involved is so great that this method is seldom used. The two-speed motor with 2:1 ratio, however, is a regularly listed standard motor and is frequently used where half-speed and full torque is desired, as in air-compressor operation.

Other methods of speed control, by the use of two or more motors in various combinations, are possible, but these are special problems.

Converting Apparatus

Although most power requirements can be met by the direct application of alternating-current motors, there are many applications of electric power which compel the use of apparatus for converting alternating into direct current; as, for instance, electrolytic work or the operation of direct-current motors for railway or other variable-speed purposes. In such a case the choice lies usually between motor-generator sets and rotary converters, with a limited use of the mercury arc or other types of so-called "rectifiers."

The motor-generator set, as its name implies, consists of an alternating-current motor driving a direct-current generator, which may, of course, be either belted or direct coupled if both machines have approximately like speeds. Such a combination possesses infinite flexibility, as obviously the motor and the generator may each be designed for the conditions as they exist; for instance, a 10,000-volt motor may be used to drive a low-voltage direct-current generator, while a rotary converter operates with an approximately fixed ratio between the a.c. and d.c. voltages. The motor-generator set has, however, certain disadvantages, among which are larger size and first cost and lower efficiency due to the double conversion of energy from electricity into mechanical power and back again.

The rotary converter, rotary transformer, or synchronous condenser as it is variously called, may be said to consist of a synchronous motor and a direct-current generator in one and the same piece of apparatus. It has a stationary field frame and a revolving armature having a commutator on one end as in an ordinary direct-current generator, and on the other end collector-rings and brushes as in an ordinary synchronous motor of the revolving-armature type. In this machine the alternating current is introduced into the armature winding through the collector rings and is commutated or rectified into a uni-directional or direct current by the revolving commutator, thus being converted without passing through the transformations involved in the motor-generator set. For this reason the overall efficiency of the rotary converter is usually higher than that of the motor-generator set, and due to its more compact construction its cost may be kept low. It has the disadvantage, however, of involving synchronous operation which is seldom clearly understood by the average operator, and also the disadvantage of having a fixed ratio between the voltage of the alternating current supplied, and the voltage of the direct current furnished by it. This ratio approximates 1 to 0.7, with slight variations according to the method of connection used. In the case of a converter delivering 250 volts direct current it would have to be supplied with alternating current at approximately 175 volts. Obviously to furnish a low alternating voltage from a transmission system carrying say 10,000 volts would require additional static transformers for this purpose, and it is the cost of this and other auxiliary equipment that frequently results in the use of the motor-generator set in preference.

Various methods have been introduced to vary the delivered voltage of a rotary converter, the customary ones being to vary the applied a.c. voltage by means of switches or induction regulators; or the use of the so-called "booster" converter, which consists of an additional winding on the converter armature which is influenced by a second or auxiliary field winding. Either of these methods is effective over a limited commercial range, but neither approximates the flexibility of the motor-generator combination.

Starting and Protective Apparatus

Intelligent selection of motor equipment should in every case be accompanied by similar attention to the starting and protective apparatus with which motors are supplied, as too often this essential detail is neglected, with the result that the motor operation is unsatisfactory when in reality the motor itself is in no way at fault. Instances almost without number might be cited to illustrate this point, but one or two selected from personal experience will be fairly representative.

In a mine-pumping installation consisting of plunger pumps driven by slip-ring motors, float-controlled automatic starting apparatus was specified, which was to have the period of acceleration adjustable up to one minute. Through an error, "current limit" control only was furnished, which in this case brought the motors up to speed in three or four seconds. This rapid acceleration was in no way injurious to the motor but had disastrous effects elsewhere, as the water pressure resulting from the inertia of the column of water in the discharge line was so great that one valve-body and two flanged connections were burst during the enforced operation of this equipment. Upon the substitution of a starting device having a fixed time element no further trouble was experienced, as the period of acceleration was lengthened to nearly fifteen seconds and the column of water was put in motion with hardly any perceptible rise in pressure.

In another instance some delicate and complex apparatus which was ideal in its theory was installed in a sampling mill, in a location where it was impossible to entirely protect it from the omnipresent sulphide dust. The result was that within less than a week the equipment was absolutely inoperative, and it was eventually replaced with other apparatus which was both cheaper and better able to stand up under the severe service conditions imposed.

Three-phase squirrel-cage motor starters may be classed under types as "star-delta," "resistance," and "compensator;" and under methods of operation as "hand-operated," "master-control," and "automatic." Each type can, of course, be operated by any method, so it is obvious that there are abundant alternatives to choose from.

The "star-delta" starter is one of the simplest forms and takes its name from the two ways in which the motor coils can be grouped. When the phase circuits of a motor designed for delta-connected operation are connected in star, the resulting combination would require 173 per cent of normal voltage to secure normal operating conditions. As the normal available voltage is only 57 per cent of this amount, the application of this voltage to the star combination is equivalent to a 43 per cent reduction of voltage applied to the delta combination which is the normal operating combination for which the motor was designed. This potential, as was shown when discussing motor starting characteristics, is sufficient to secure satisfactory starting under certain conditions. As it offers, however, only one starting torque, which may be greater or less than is desired in any specific case, it lacks the flexibility of the other systems. It also has the disadvantage of requiring six wires between the motor and the starting switch instead of the three required by other systems.

The "resistance" method of starting consists of merely inserting an ohmic or non-inductive resistance into the primary circuit, which results in lowering the voltage applied to the motor during the starting period. This is a highly inefficient method of starting, as the line current remains very high, the difference between the line voltage and that applied at the motor terminals being absorbed by the resistance, and the energy represented by it being dissipated in the form of heat. The resistance starter has the one advantage of being cheap in the small sizes, and it has secured a limited recognition for this reason.

The "compensator" method of starting is the one most generally used with squirrel-cage motors, and is standardized in various forms by practically every motor builder. It consists of a case containing either two or three auto-transformer or compensating coils, and a switching device by which a reduced potential obtained from the transformer coils may be applied to the motor terminals during the starting period. When the motor has attained full speed a second operation of the device disconnects the transformer coils and connects the motor directly to the line. By arranging for various taps or connections to the coils the starting voltage obtained from them may be conveniently changed to suit the requirements of the individual motor with which the compensator is used.

Starters for phase-wound motors have, of course, but one type, that of varying the rotor resistance. Motors having this resistance carried inside the rotor (the so-called "internal-resistance" type) are of value chiefly for obtaining easy acceleration with a minimum amount of line disturbance, their ability to start heavy loads being limited by the ability of the resistors to dissipate the heat generated during the starting period. A 15 to 30-second period of acceleration for normal load is the rating of one of the standard motors of this type

now on the market, but if either the load or the time factor is likely to be materially exceeded the purchaser should consider the use of the slip-ring motor with external resistors and switching device or controller, as it is usually termed.

Regarding methods of control, regardless of motor types, certain considerations should always be kept in mind. The familiar types of hand-operated starters are too well known to need comment here, but the introduction of large motors has brought with it a condition that has resulted in the development of "master-control" for two reasons: (1) The necessity for means to limit the rate of acceleration, and to prevent motor abuse, and (2) the necessity for means of controlling motors, the starting equipment of which is too large for manual operation, or which may be located at a distance from the operator.

The control developed to meet the first of these was largely due to the introduction of electrical equipment into industrial fields where the operators were either unable or unwilling to use discretion in handling it. Briefly, it consists of automatic switching devices which control the motor in all its functions exactly as its designer intended; the operator in charge having no control over it except to determine when it is to start and stop, and in some cases the direction of its rotation. The operator handles only the master-controller or "master-switch," as it is sometimes called, the controller proper consisting of a panel with the necessary electrically actuated switches and automatic relays on it, which may be located near the motor, or if desired, in a more protected place. The relays referred to prevent too rapid acceleration, and this style of control equipment as a whole has resulted in a remarkable decrease in the maintenance cost of the motors, as the brains of an expert are substituted for those of the average operator who may be and often is entirely ignorant of the equipment placed in his charge.

The second reason cited is also an outcome of the same conditions, as the increasingly large size of motors now frequently installed require starting and control apparatus of a size that is entirely too large to be handled manually, and these motors are also, as a rule, placed some distance from the operator. Another condition frequently arising is the simultaneous control of two or more motors by one operator. This condition is best typified by the "multiple-unit" control developed for railway motor cars, where the motors on all the cars of a train are controlled simultaneously from one point, or as in certain manufacturing establishments where a group of motors in a department are sometimes controlled from one location.

From master-control to automatic-control is only a short step, the substitution of the automatically-operated master or pilot switch for the hand-operated being merely a detail. There are, however, two general types of automatic-control which are seldom clearly understood, viz.: current-limit control and time-element control, and a brief consideration of these may be in order.

Current-limit control, as its name implies, consists of switches and relays so designed as to limit the current passing to a certain predetermined maximum. In itself this is an excellent thing, but it can easily be seen that it involves acceleration at all times at a current rate equal to the maximum that may be required by the motor at full-load full-speed conditions, as it is obvious that unless the relays are so adjusted there may occur conditions of starting load which the motor could not accelerate with less than full-load current, and, of course, the control equipment cannot be expected to differentiate between a light and a heavy starting load condition. This state of affairs may, and usually does, result in light-load starting at an objectionably rapid rate of acceleration, simply because the control equipment must of necessity be left so adjusted that it can take care of the occasional heavy-load starting conditions that may occur. Under such conditions the introduction of a time element into the control system is most desirable, as it can be made to assure an almost uniform starting performance regardless of load conditions.

Assume for instance a 50-h.p. motor driving a crusher, which, when the crusher is empty, has merely to accelerate itself and the crusher flywheels. When the crusher is more or less choked the motor will have to exert additional starting torque, depending upon the amount of choking, up to perhaps two or three times its normal full-load running torque. In such a case the starting equipment would have a time element of say forty seconds, cutting out the starting resistance in steps at fixed intervals regardless of the resulting current conditions. Under such conditions if the crusher were only slightly choked the motor would start it on say the second or third point of the control, and if the crusher were badly choked it might not start until the fourth or fifth of the six or eight steps provided. Overload protection would be required only in case it was impossible to start the crusher, and the resulting motor overloads were to continue for a considerable length of time. Under such conditions an overload circuit breaker having a time element incorporated in it should be installed, which would permit the brief overloads, such as starting peaks, to exist, but which would open instantly in case of dangerous overloads or in case of light overloads continuing for a considerable length of time. Such circuit breakers are standard commercial articles.

Protective Apparatus

In the matter of protective apparatus for alternating-current motors there is not a great deal to be said, the choice between circuit breakers and fuses being usually a matter of local conditions and personal preference. There are, however, two details which are not always given the consideration that they merit, namely, protection in case of interruption of current supply, and protection against single-phase operation in the case of polyphase motors.

The result of applying full voltage to a circuit to which one or more induction motors may be connected is, of course, equivalent to closing switches at the motors themselves. Under this condition, as stated before, the motor, unless provided with automatic starting equipment, will take from seven to nine times its normal full-load running current, which, while it may not injure the motor, will result in an extremely sudden start unless, as is usually the case, the fuse or other protective apparatus acts and disconnects the motor from the line. While the effect on the motor of such treatment may not be injurious, and while the trouble and expense of replacing the protective equipment may be bearable, yet it is easy to see that if all the motors on a system were operated in this way the enormous momentary current necessary to operate all the overload protective devices on the system under such conditions would be so great that no available generating capacity could supply it, and it would be impossible to again get full voltage on the line. For this reason every motor should be supplied with some form of device that will automatically disconnect it from the line in case of an interruption to the energy supply. The majority of motor starters for squirrel-cage motors have this function incorporated in their design, and for phase-wound motor operation there are available automatic switches or circuit breakers which have this "no voltage release" attachment.

When one phase of a polyphase motor circuit is opened while the motor is in operation the motor will continue to run without apparent distress unless heavily loaded. It will, however, have its entire load concentrated on the one phase winding left in service, and this will in most cases constitute an overload on this part of the winding which, if allowed to continue, will eventually burn out and destroy the winding. It is important, therefore, that protective apparatus should be employed which, in the event of the opening of any one phase, will entirely disconnect the motor from the line, thus preventing single-phase operation and consequent damage. Unfortunately this fact is not fully appreciated, with the result that fuses are still largely employed, which of course can, and frequently do, burn out in one phase from some momentary overload condition, leaving the motor to run single-phase until it burns out, or the fact is discovered through its refusal to start subsequently. A three-phase motor running on single-phase emits a characteristic hum or buzz which is entirely different from the sound heard under normal operation, and any engineer or operative in charge of any such motors should familiarize himself with it, as much trouble may often be avoided thereby.

While much of the foregoing may seem elementary to those well acquainted with modern motor equipment and practice, yet it has been the writer's experience that much of it is unfamiliar to many engineers skilled in other lines, and it is hoped that to some of these it may prove of interest and possibly of value.

Denver, Colo.

Melting Points of Chemical Elements and Other Standard Temperatures

The following tables are reproduced from Circular No. 35 (second edition) of the United States Bureau of Standards as they should prove exceedingly handy for use.

The values of the melting points used by the Bureau of Standards as standard temperatures for the calibration of thermometers and pyrometers are indicated in capitals. The other values have been assigned after a careful survey of all the available data.

As nearly as may be, all values, in particular the standard points, have been reduced to a common scale, the thermodynamic scale. For high temperatures, and for use with optical pyrometers, this scale is satisfied very exactly by taking $c_2 = 14{,}500$ in the formula for Wien's law connecting I, monochromatic luminous intensity of wave length λ, and T, absolute temperature: $\log I/I_1 = c_2\lambda \log e(1/T_1 - 1/T)$. For all purposes, except the most accurate investigations, the thermodynamic scale is identical with any of the gas scales.

At high temperatures some of the values are quite uncertain; thus, while the melting point of platinum may be considered accurately known to 5 deg. C., that of tungsten is uncertain by 100 deg. C. or more. Temperatures centigrade are rounded off, and the exact Fahrenheit equivalents are usually given.

MELTING POINTS OF THE CHEMICAL ELEMENTS

Element	C	F	Element	C	F
Helium	<−271	<−456	Arsenic	850?	1562
Hydrogen	−259	−434	Barium	850	1562
Neon	−253?	−423	Praseodymium	940?	1724
Fluorine	−223	−369	Germanium	958	1756
Oxygen	−218	−360	SILVER	960.5	1761
Nitrogen	−210	−346	GOLD	1063.0	1945.5
Argon	−188	−306	COPPER	1083.0	1981.5
Krypton	−169	−272	Manganese	1260	2300
Xenon	−140	−220	Samarium	1300–1400	2370–2550
Chlorine	−101.5	−150.7	Beryllium (Glucinum)	1350?	2462
MERCURY	− 38.9	− 38.0	Scandium	?	.....
Bromine	− 7.3	+ 18.9	Silicon	1420	2588
Caesium	+ 26	79	NICKEL	1452	2646
Gallium	30	86	Cobalt	1480	2696
Rubidium	38	100	Yttrium	1490	2714
Phosphorus	44	111.2	Chromium	1520	2768
Potassium	62.3	144	IRON	1530	2786
Sodium	97.5	207.5	PALLADIUM	1549	2820
Iodine	113.5	236.3	Zirconium	1700?	3090
Sulphur	S_I 112.8 S_{II} 119.2 S_{Iu} 106.8	235.0 246.6 224.2	Columbium (Niobium)	1700?	3090
Indium	155	311	Thorium	>1700 <Pt.	>3090 <Pt.
Lithium	186	367	Vanadium	1720	3128
Selenium	217–220	422–428	PLATINUM	1755	3191
TIN	231.9	449.4	Ytterbium	?	.....
Bismuth	271	520	Titanium	1800	3272
Thallium	302	576	Uranium	<1850	<3362
CADMIUM	320.9	609.6	Rhodium	1950	3542
LEAD	327.4	621.3	Boron	2200–2500?	4000–4500
ZINC	419.4	786.9	Iridium	2350?	4262
Tellurium	452	846	Ruthenium	2450?	4442
ANTIMONY	630.0	1166	Molybdenum	2500?	4500
Cerium	640	1184	Osmium	2700?	4900
Magnesium	651	1204	Tantalum	2850	5160
ALUMINIUM	658.7	1217.7	TUNGSTEN	3000	5430
Radium	700	1292	Carbon	>3600 for p=1 At.	>6500 for p=1At.
Calcium	810	1490			
Lanthanum	810?	1490			
Strontium	>Ca<Ba?	.....			
Neodymium	840?	1544			

OTHER STANDARD TEMPERATURES

Substance	Phenomenon	C	F	Variation with pressure (pressure in mm of Hg)
OXYGEN	Boiling	−183.0	−297.4	$C° = -183.0 + 0.01258\,(p-760) - 0.0000079\,(p-760)^2$
CARBON DIOXIDE	Sublimation in inert liquid	− 78.5	−109.3	$C° = -78.5 + 0.017\,(p-760)$
SODIUM SULPHATE $Na_2SO_4 + 10H_2O$	Transformation into anhydrous salt	32.384	90.291	
WATER	Boiling	100	212	$C° = 100 + 0.03670\,(p-760) - 0.00002046\,(p-760)^2$
NAPHTHALENE	do	217.96	423.73	$C° = 217.96 + 0.058\,(p-760)$
BENZOPHENONE	do	305.9	582.6	$C° = 305.9 + 0.063\,(p-760)$
SULPHUR	do	444.6	832.3	$C° = 444.6 + 0.0908\,(p-760) - 0.000047\,(p-760)^2$
Ag_2Cu_2	Eutectic freezing	779	1434	
SODIUM CHLORIDE	Freezing	801	1472	

The Arizona Copper Co. produced 1600 tons of copper during the month of February, 1915.

The German Kali Syndicate production of potash in 1914 was valued at about $37,128,000. This was a decrease in comparison with 1913 when the value was $45,696,000. But for the war it is estimated that the value for 1914 would have been about $49,980,000.

The importation of chemicals, drugs and dyes into the United States has average $7,700,000 per month during the last five years. In August, 1914, the total fell to $5,622,000 and in September to $5,519,000; but in November the amount had increased to nearly $8,000,000. Imports of sodium cyanide last July amounted to 134,000 pounds. This fell to 84,000 pounds in August, but rose to 2,182,000 pounds in November.

The Formation and Decomposition of Sulphates During Roasting

BY BOYD DUDLEY, JR.

(*Concluded from page* 226)

II. The Effect of Reaction Velocity

The velocity of a reaction occurring between the phases of an heterogeneous system is largely dependent upon the extent and the nature of the separating surface between the reacting phases. It also depends upon other circumstances of a secondary nature, such as the diffusion capacities of the liquid or gaseous reactants, and the velocity of stirring. Furthermore, it is highly probable that at every boundary between two phases equilibrium is established at a practically infinite velocity, as compared with the rates of diffusion.[8] These principles have been tested by various investigations of reaction velocity between solid and liquid phases, and have been found to hold good. While experimental proofs are lacking, there appear no good reasons why the velocities of reactions between solid and gas phases at high temperatures should not be governed by like considerations. Assuming such to be the case and applying these principles to the question of the rate of sulphate formation and decomposition, the following conceptions may be advanced.

Assume a mixture of a metal sulphate, which decomposes directly into oxide, and the corresponding oxide to be placed in a heated space containing a definite partial pressure of sulphur trioxide. The gas film in immediate contact with the solids will at all times contain sulphur trioxide to the amount corresponding to the dissociation tension of the sulphate at the prevailing temperature.

Whether the sulphate is decomposed or the oxide is sulphatized is determined by whether the dissociation tension of the sulphate is greater than or less than the partial pressure of the sulphur trioxide in the gas outside of the contact film. The rate at which the sulphate is decomposed or the oxide sulphatized depends upon the rate at which the sulphur trioxide diffuses through the contact film from the sulphate to the gas outside the film in the former case, or upon its rate of diffusion from the gas to the surface of the oxide in the latter. In either event diffusion is the controlling factor; conditions that accelerate it will increase the reaction velocity, and conditions that retard it will retard the reaction.

The rate of diffusion in any case depends mainly upon three factors, which are, the diffusion co-efficient of the gas, which in general shows rapid increase with increasing temperature, the difference between the dissociation tension of the sulphate and the partial pressure of sulphur trioxide in the gas, and the thickness of the contact film surrounding the solids.

From these facts it appears that, other things being equal, the rate at which a sulphate will be formed or decomposed will increase with increasing temperature, with increasing difference between the dissociation tension of the sulphate and the partial pressure of sulphur trioxide in the gas phase, and with increasing rate of stirring. The effect of stirring is to reduce the thickness of the contact gas film between the solid and the gas phases. It is, of course, understood that the direction of the reaction is determined by the partial pressure of the sulphur trioxide in the gas phase as compared with the dissociation tension of the sulphate at the prevailing temperature.

While the above conceptions probably represent the main features of the question of reaction velocity under the conditions being discussed, in any attempt to apply them to the study of reactions in the roasting furnace the following facts, which have been emphasized before but which are of sufficient importance to be repeated, must be borne clearly in mind. Usually in the roasting furnace an ore bed several inches in depth is treated, and, therefore, the conditions existing in the interstices of the bed at any given point are usually quite different from those existing at the surface of the bed. Consequently it is possible to have particles of a given sulphate undergoing rapid dissociation at a point on the surface of the bed of ore, while at some depth the rate of dissociation of this compound may be insignificant. In fact, due to high sulphur trioxide concentrations in the interstices of the ore bed resulting perhaps from the decomposition of a sulphate that has a high dissociation tension at the prevailing temperature, the oxide of a metal may undergo sulphatization in the deeper portions of the bed at the same time that its sulphate is being decomposed at the top of the bed.

An interesting example of the effect of the difference between the dissociation tension of the sulphate and the partial pressure of sulphur trioxide in the furnace gas upon the rate of dissociation of a sulphate is furnished by following at constant temperature the process of the complete decomposition of a sulphate that produces first a basic sulphate and then the metal oxide. As was mentioned in a preceding paragraph, basic sulphates resulting from the decomposition of the normal compounds

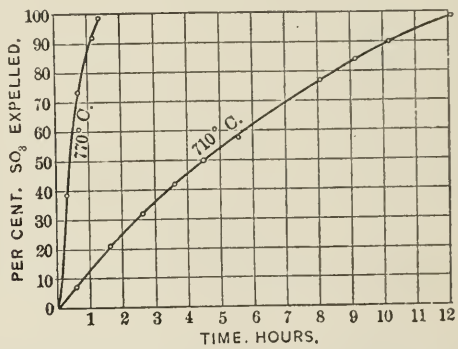


FIG. 5—VELOCITY OF DECOMPOSITION IN A CURRENT OF AIR OF Ni_1SO_4 AT 710 DEG. AND 770 DEG. C.

have in general at given temperatures lower dissociation tensions than have the sulphates from which they are produced.

Heating a thin layer of a sulphate that dissociates directly to oxide at constant temperature in a current of dry air should, in view of the arguments that have been advanced, produce a nearly constant rate of decomposition. The rate will, of course, decrease somewhat as complete decomposition is approached, due to the obstruction of the process of diffusion by the oxide produced.

On the other hand, if a sulphate that dissociates first into a basic compound is heated under similar conditions, the rate of decomposition will remain practically constant only until complete conversion of the normal sulphate into the basic compound has occurred. The basic sulphate, having at the prevailing temperature a lower dissociation tension than the normal compound, will maintain a lesser difference between the sulphur trioxide concentration of the contact film and that of the gas as a whole than did the normal sulphate. Other conditions remaining the same as before, a new and slower rate of diffusion of the sulphur trioxide from the sulphate to the gas will be established, and the rate of decomposition of the compound will be correspondingly reduced. Or rather the changed conditions will establish the rate of decomposition of the basic sulphate at a

[8] Nernst, Theoretical Chemistry, Translation of 6th Ger. Ed., p. 584

lower figure than that of the normal sulphate. These points are nicely illustrated by two typical curves from the experiments of Hofman and Wanjukow.[9]

Fig. 5 shows the rates of decomposition of 0.3 g. of crystalline nickel sulphate at 710 deg. and at 770 deg., after the crystalline salt had been dehydrated. In this case no basic sulphates are produced, the curves being smooth and nearly straight. Fig. 6 shows the rate of decomposition of a like amount of cadmium sulphate at 960 deg. A marked change in the rate of decomposition is observed when about 80 per cent of the sulphur trioxide has been evolved, which indicates the formation of a basic sulphate containing one-fifth as much sulphur trioxide as the normal sulphate. The formula of the basic compound may, therefore, be written $5CdO \cdot SO_3$. By other and independent methods the composition of the salt was determined and found to correspond to this formula. It is evident that by following the rate of decomposition of a sulphate in the manner described it is possible, by this procedure alone, to detect the formation of basic sulphates and to establish the composition of the compounds formed.

In the discussion of the factors that regulate the velocity with which sulphates are formed or decomposed, to simplify matters, only the process of the diffusion of sulphur trioxide from the surface of the sul-

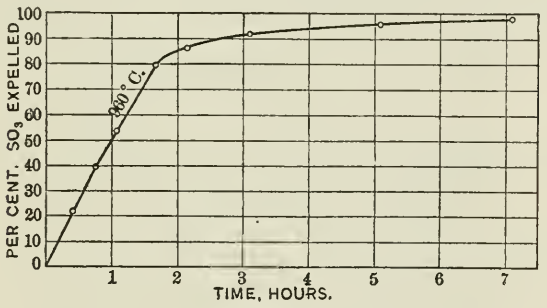


FIG. 6—VELOCITY OF DECOMPOSITION IN A CURRENT OF DRY AIR OF $CdSO_4$ AT 960 DEG. C.

phate undergoing decomposition or to the surface of the oxide undergoing sulphatization was considered. As a matter of fact the dissociation of the sulphur trioxide plays a most important part with reference to the velocity of such reactions.

To illustrate, consider the dissociation of a metal sulphate at constant temperature and under constant conditions of air current, thickness of the layer of sulphate, etc. In most cases the temperature is such that the sulphur trioxide evolved from the sulphate tends to dissociate according to the reaction.

$$2SO_3 = 2SO_2 + O_2.$$

As may be seen from the equation, this dissociation is accompanied by an increase in the gas volume. Accordingly, the process of sulphur trioxide dissociation will assist diffusion in the removal of sulphur trioxide from the film in contact with the sulphate. Likewise the dissociation of sulphur trioxide within the interstices of the bed of material being treated will accelerate the removal of the compound from these spaces.

It follows that the rate of dissociation of a sulphate depends not only upon the factors affecting the diffusion rate of sulphur trioxide, but also upon the rate and the completeness of the dissociation of this compound. By accelerating the rate of dissociation of the sulphur trioxide evolved from a metal sulphate and by increasing the completeness of this dissociation the rate of dissociation of the sulphate should be correspondingly increased. The degree to which sulphur trioxide will dissociate depends mainly upon the temperature, while the rate at which this compound dissociates and comes to equilibrium with its dissociation products is mainly determined by the presence or absence of efficient catalysts.

It has been already explained that contact with such substances as platinized asbestos and similar materials will greatly accelerate the reaction between the sulphur oxides and oxygen, and that certain metal oxides as ferric oxide will exert a similar influence but to a lesser degree. These facts lead naturally to the conclusion that the rate of sulphate decomposition in the roasting furnace will, other things being equal, depend to some degree upon the presence in, or absence from, the roasting ore of catalysts, ferric oxide being probably the most important material in this respect that is of common occurrence under such conditions.

The above remarks may be extended to cover the process of sulphate formation, when the conditions assumed are such as might result in the formation of a sulphate through the oxidation of sulphur dioxide and the union of the sulphur trioxide thus formed with the metal oxide. Inasmuch as this process is simply the reverse of the one that has been discussed above, it is considered unnecessary to describe it in detail.

This theory concerning the influence of admixed materials upon the rate of decomposition of sulphates has been tested by the writer in the following manner.

Aluminium sulphate (nearly anhydrous) contained in a porcelain boat was heated at constant temperature in an electric tube furnace, a current of dry air being meanwhile passed through the tube. The rate of decomposition of the sulphate was determined by removing the boat from the furnace at intervals of one-half hour and weighing. Then at the same temperature a mixture of the sulphate with ferric oxide was treated in a similar manner. As will be shown by the following detailed account of the experiments, the rate of decomposition of the sulphate was in all cases accelerated by mixing it with iron oxide. Analysis of the gases escaping from the furnace tube showed that the acceleration of the sulphate decomposition is attributable to the catalytic effect of the ferric oxide upon the dissociation of sulphur trioxide.

Aluminium sulphate was selected not because of its importance in a metallurgical sense, but because it forms no basic sulphate, and because at the temperatures involved there seemed little likelihood of complications arising due to the direct union of alumina with the ferric oxide. It was desired to show that the action of the ferric oxide in accelerating the dissociation of sulphates does not necessarily depend, as has been stated,[10] upon its union with the metal oxide to form ferrite. It may, and usually does, function simply as a catalyst. Therefore, a sulphate was chosen the oxide of which has not been observed to unite with ferric oxide at the ordinary temperatures of roasting.

Kahlbaum's crystalline aluminium sulphate (Grade I) was partly dehydrated by heating in a porcelain dish over a gas flame. The caked material from this operation was pulverized and subjected to further dehydration in the electric tube furnace. The heating was conducted at a temperature of about 350 deg. Owing to insufficient time being given to this operation the material was not completely dehydrated, the analysis showing

Al_2O_3 ..... 28.41 per cent
SO_3 ..... 66.50 per cent
H_2O ..... 5.09 per cent (by difference).

The presence of this quantity of water was not detrimental, it being expelled during the first few minutes of heating at the temperatures employed in the experiments. The loss in weight during the first half-hour

[9] Loc. Cit.

period of the heating was, therefore, water and sulphur trioxide, the amount of sulphur trioxide being obtained by subtracting 5.09 per cent of the weight of sulphate taken from the total loss in weight.

The ferric oxide was prepared by first dehydrating and then calcining in a muffle furnace Kahlbaum's crystallized ferric nitrate (Grade 1). This material was not analyzed, but was tested by ignition in an open crucible, showing neither loss nor gain in weight.

The arrangement of the apparatus is shown in Fig. 7. In the preliminary experiments the exit end of the furnace tube was left open, but later, when it was desired to determine sulphur dioxide in the gas, the arrangement was as the figure shows.

In the first tests 0.5 g. of the prepared sulphate contained in a porcelain boat was heated in the furnace in a current of dry air at 800 deg. At the end of each

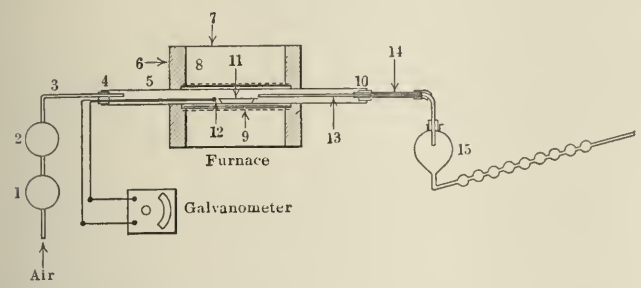


FIG. 7—DIAGRAM OF APPARATUS USED IN DETERMINING RATES OF DISSOCIATION OF $Al_2(SO_4)_3$

1—Wash bottle containing KOH solution. 2—Wash bottle containing H_2SO_4. 3—Glass tube to deliver air to furnace tube. 4—Two-hole rubber stopper. 5—Silica combustion tube, 24 in. long by 1 in. inside diameter. 6—Asbestos wood end of furnace. 7—Galvanized iron shell of furnace, 12 in. long by 9 in. diameter. 8—Magnesia for heat insulation. 9—Alundum cylinder, 10 in. long by 2 in. inside diameter; with spiral groove, 9 threads per inch on outside, to hold 16 B. & S. gauge Excello resistance wire. 10—One-hole rubber stopper. 11—Porcelain boat containing sulphate. 12—Junction of thermo couple, actual position was nearer to boat than is shown. 13—Silica tube, 1 mm. bore, for removing gaseous decomposition products rapidly from furnace. 14—Glass tube into which silica tube (13) was sealed with wax cement, for protection of silica tube. 15—Absorption tube containing standard iodine solution for the determination of SO_2.

half hour the boat was removed from the furnace and weighed. The loss in weight during the first period was sulphur trioxide and water; during the subsequent periods the losses were sulphur trioxide only. During the periods when the boat was not in the furnace, i. e., during the cooling preparatory to weighing and during weighing, the boat was handled carefully in order not to disturb or stir its contents. Owing to the fact that the depth of the sulphate powder in the boat amounted to about 2 mm., either thorough stirring between each heat or no stirring at all should be employed, if consistent results are expected. A mixture of 0.5 g. of the prepared aluminium sulphate with 0.2 g. of the prepared ferric oxide was subjected to the same treatment. The results obtained are shown in Table VIII.

TABLE VIII—LOSSES OF SULPHUR TRIOXIDE SUSTAINED BY 0.5 G. OF ALUMINIUM SULPHATE WHEN HEATED ALONE AT 800°, AND WHEN HEATED WITH FERRIC OXIDE

ALUMINIUM SULPHATE ALONE		ALUMINIUM SULPHATE+FERRIC OXIDE	
SO_3 Losses in Half-hour Periods	Cumulative Loss of SO_3	SO_3 Losses in Half-hour Periods	Cumulative Loss of SO_3
0.0210 g.	0.0210 g.	0.0309 g.	0.0309 g.
169	379	255	564
129	508	214	778
100	608	175	953

The results thus obtained indicate clearly that the rate of dissociation of the sulphate is greater when it is heated with the ferric oxide than when it is heated alone. Close microscopic examination of the mixture at the end of these heatings failed to show any indications of the formation of a compound between the ferric oxide and the other constituents of the mixture.

A second series of tests were performed wherein 0.5 g. of the prepared aluminium sulphate was heated for two and one-half hours at 735 deg. The boat was removed from the furnace at the end of each half hour and weighed. Then, after carefully but thoroughly stirring the sulphate, the boat and its contents were returned to the furnace. After heating in this manner for two and one-half hours or five half-hour periods, 0.2 g. of the ferric oxide was mixed with the material in the boat, and the mixture was subjected to further heating at the same temperature. The results are given in Table IX.

In this case it is seen that the addition of the ferric oxide practically doubled the rate of dissociation of the sulphate. The change in the velocity of decomposition after the addition of the ferric oxide is strikingly shown by plotting to scale the data of Table IX. This has been done in Fig. 8.

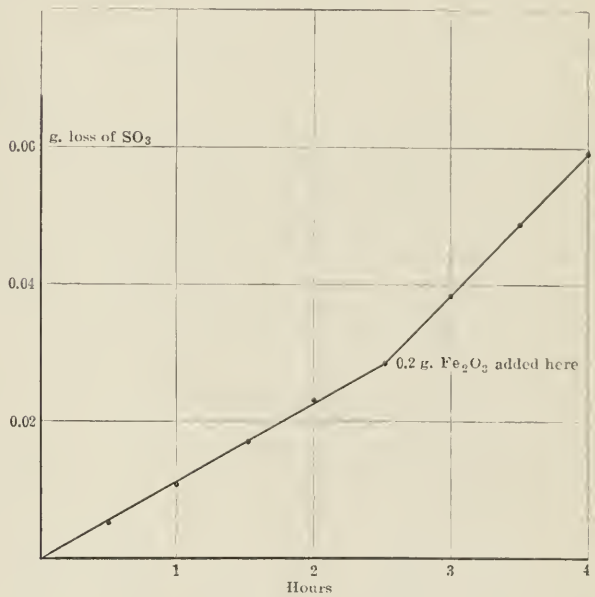


FIG. 8—RATE OF DECOMPOSITION OF $Al_2(SO_4)_3$ (0.5 G.) HEATED IN CURRENT OF DRY AIR AT 735 DEG., FIRST ALONE AND THEN WITH 0.2 G. OF FE_2O_3

In order to establish the fact that the increase in the velocity of dissociation in the presence of ferric oxide is due to the catalytic effect of this compound upon the dissociation of the sulphur trioxide, a third series of tests was made, in which the ratio of sulphur trioxide to sulphur dioxide in the gas evolved from the sulphate was determined. In order for such a determination to be of value it is necessary to catch the gaseous dissociation products of the sulphate at a point near the surface of the decomposing compound, and to convey them out of the heated space as rapidly as possible. Otherwise the slow passage of the gas through the

TABLE IX—LOSSES OF SO_3 FROM 0.5 G. OF ALUMINIUM SULPHATE HEATED ALONE AT 735° THEN MIXED WITH Fe_2O_3 AND HEATED

Losses of SO_3 in Successive Half-Hour Periods	Cumulative Loss of SO_3
0.0057 g.	0.0057 g.
56	113
55	168
58	226
55	281
102*	383
100	483
98	581

*Fe_2O_3 added previous to this heating.

[10] Mostowitsch, Metallurgie, VIII, 771, 1911.

silica furnace tube is quite likely to produce an alteration in its composition due to reaction between the sulphur oxides and oxygen.

Accordingly, in this series of experiments the air was introduced into the furnace tube as usual, but was removed, together with the gaseous dissociation products of the sulphate, through a silica tube of 1 mm. internal diameter, which was inserted into the furnace tube in the position shown in Fig. 7. From the small silica tube the gas passed through an absorption tube containing a known amount of standard iodine solution, which absorbs surphur dioxide according to the equation

$$SO_2 + I_2 + 2H_2O = H_2SO_4 + 2HI.$$

At the end of the heating period the iodine solution was washed from the absorption tube into a beaker, and the excess or unconsumed iodine was determined by titration with a standard sodium thiosulphate solution, using starch as the indicator.

In this manner the amount of sulphur dioxide in the dissociation products of the sulphate was determined. The total amount of sulphur trioxide evolved from the sulphate during the same period was given by the loss in weight sustained by the boat and its contents. The sulphur trioxide remaining undecomposed in the gas is found by calculating the amount of sulphur trioxide equivalent to the amount of sulphur dioxide found, and then subtracting this quantity from the total amount of sulphur trioxide evolved from the sulphate.

One gram of the prepared aluminium sulphate contained in a porcelain boat was heated in the tube furnace at 800°, the gas being removed and analyzed as above described. At half-hour intervals the boat was removed from the furnace and weighed. The sulphate was then stirred, and the boat was returned to the furnace. The results are given in Table X.

Table X—Rate of Dissociation and Analysis of Gas Evolved, when Aluminium Sulphate (1.0 G.) was Heated in Current of Air at 800°

Total Time of Heating	SO_3 Loss in 0.5 Hour	Cumulative SO_3 Loss	SO_2 Found in Gas	SO_3 Equiv. to SO_2	SO_3 in Gas	Vol. Ratio SO_3 to SO_2
0.5 hr.	0.0484 g.	0.0484 g.	0.0040 g.	0.0050 g.	0.0434 g.	8.7
1.0	435	919	32	40	395	9.9
1.5	432	1351	30	38	394	11
2.0	466	1817	23	29	437	15
2.5	542	2359	47	59	483	8.1
3.0	475	2834	35	44	431	9.9
3.5	415	3249	27	34	381	11
4.0	420	3669	28	35	385	11
4.5	415	4086	26	33	382	12
					Average=	11

The volume ratios of sulphur trioxide to sulphur dioxide in the last column are calculated from the weights of the gases by dividing the gas weights by the molecular weights of the respective gases. Thus,

$$\frac{\text{Volume } SO_3}{\text{Volume } SO_2} = \frac{\text{Weight } SO_3/80}{\text{Weight } SO_2/64} = \frac{\text{Weight } SO_3}{\text{Weight } SO_2} \times 0.8$$

While the ratios of sulphur trioxide to sulphur dioxide as determined during this experiment are not in close agreement, they indicate with all necessary accuracy the conditions existing within the furnace tube at a point close to the decomposing sulphate. In fact, considering the probable error of the determinations of such small amounts of sulphur dioxide, such variations in the ratio are to be expected. The average ratio of eleven volumes of sulphur trioxide to one of sulphur dioxide indicates only a slight dissociation of the sulphur trioxide. Hence the rate of dissociation of the sulphate was in this case mainly dependent upon the rate of diffusion of the sulphur trioxide from the surface of the solid.

A similar test was made at 800° under the same conditions as the preceding, only in this case 1.0 g. of the prepared aluminium sulphate was mixed with 0.2 g. of the ferric oxide. The results are given in Table XI.

Table XI—Rate of Dissociation and Analysis of the Gas Evolved, when 1.0 G. of Aluminium Sulphate was Heated with 0.2 G. of Ferric Oxide at 800°

Total Time of Heating	SO_3 Loss in 0.5 Hour	Cumulative SO_3 Loss	SO_2 Found in Gas	SO_3 Equiv. to SO_3	SO_3 in Gas	Vol. Ratio SO_3 to SO_2
0.5 hr.	0.0841 g.	0.0841 g.	0.0410 g.	0.0513 g.	0.0328 g.	0.64
1.0	858	1699	379	474	384	0.81
1.5	997	2696	449	561	436	0.78
2.0	1015	3711	481	601	414	0.69
2.5	690	4401	331	414	276	0.67
3.0	620	5021	295	369	251	0.68
3.5	475	5496	226	283	192	0.68
4.0	235	5731	109	136	99	0.73
4.5	150	5881	70	88	62	0.71
					Average=	0.71

In this case, as in the preliminary experiments, the rate of dissociation of the sulphate was accelerated by the addition of ferric oxide. The average ratio of sulphur trioxide to sulphur dioxide was found to be 0.71 volumes of the former to 1 of the latter, which indicates much more complete dissociation of the sulphur trioxide than occurred when the aluminium sulphate was heated alone.

A third test was made by heating 1.0 g. of the prepared aluminium sulphate with 0.1 g. of platinized asbestos, containing about 0.025 g. of metallic platinum. The heatings were conducted for 0.5 hr. at 800° in the manner described above. The reason for trying the platinized asbestos was not on account of the possibility of any application it might have to practice, but simply to show that other catalysts will produce effects similar to that of the ferric oxide. Results are given in Table XII.

Table XII—Rate of Dissociation and Analysis of the Gas Evolved, when 1.0 G. of Aluminium Sulphate was Heated with 0.1 G. of Platinized Asbestos at 800°

Total Time of Heating	SO_3 Loss in 0.5 Hour	Cumulative SO_3 Loss	SO_2 Found in Gas	SO_3 Equiv. to SO_2	SO_3 in Gas	Vol. Ratio SO_3 to SO_2
0.5 hr.	0.1006 g.	0.1006 g.	0.0501 g.	0.0626 g.	0.0380 g.	0.61
1.0	940	1946	439	594	391	0.71
1.5	895	2841	384	480	415	0.86
					Average=	0.73

It will be observed that the rate of dissociation of the sulphate is accelerated by the presence of the finely divided platinum, the results from this test being practically the same as those obtained when the sulphate was mixed with ferric oxide. However, it should be noted that the amounts of platinum and of ferric oxide were by no means the same, the quantity of platinum required to produce a given effect being much less than of ferric oxide.

In order to show in graphical form the influence of the catalysts upon the dissociation rate of aluminium sulphate, the data of Tables X, XI and XII have been plotted to scale in Fig. 9.

It is interesting to compare the ratio of sulphur trioxide to sulphur dioxide found in these experiments with that to be found in the equilibrium mixture resulting from the dissociation of sulphur trioxide at atmospheric pressure. In the interstices of the layer of sulphate grains the sulphur trioxide tends to dissociate into sulphur dioxide and oxygen. Hence a comparison of the ratio of these two gases found experimentally with the theoretical ratio will indicate how nearly the conditions in the interstices approached the equilibrium conditions. From Table IV or Fig. 2 it is seen that at atmospheric pressure and 800° (the temperature of the experiments) sulphur trioxide alone will dissociate until its ratio to sulphur dioxide is only 0.433 to 1. From this it may be seen that the ratio of 11 to 1, obtained

when the aluminium sulphate was heated alone, indicates conditions far removed from the equilibrium; while the ratios 0.71 and 0.73 to 1, obtained in the presence of catalysts, indicate conditions near to the equilibrium.

Experiments along this line could be continued indefinitely, using other sulphates and other catalysts, but since the data so secured cannot be applied to roasting on a large scale in a quantitative manner, it is considered sufficient to have established the point in question. The results apparently leave little doubt as to the fact that ferric oxide and other catalysts will accelerate the rate of dissociation of sulphates by catalyzing the dissociation of the sulphur trioxide and thus removing it from the film of gas in contact with the sulphate at a greater rate than it would be removed by diffusion

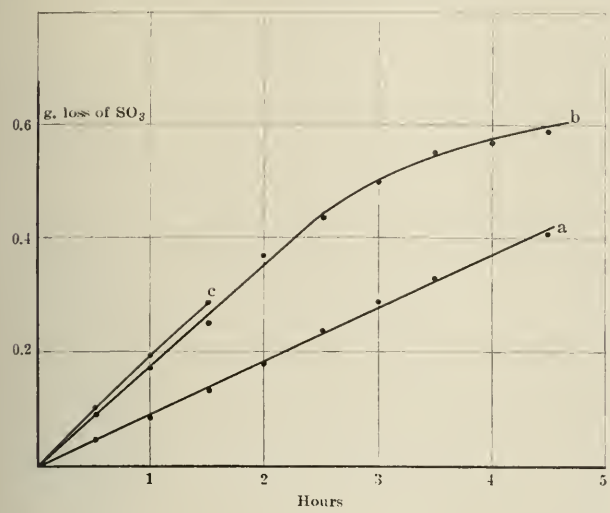


FIG. 9—RATES OF DECOMPOSITION OF $Al_2(SO_4)_3$ (1.0 G.) HEATED IN CURRENT OF DRY AIR AT 800 DEG.

a—sulphate alone; b—1 g. of sulphate with 0.2 g. of Fe_2O_3; c—1 g. of sulphate with platinized asbestos containing 0.025 g. of Pt.

alone. Ferric oxide has been considered and discussed in particular because of its very general occurrence in materials that are subjected to roasting, and because it is known to be one of the most efficient catalysts, with the exception, of course, of finely divided platinum and similar metals. However, cupric oxide is also known to be effective as a catalyst and deserves mention in this connection. Such substances as silica, alumina and probably lime are comparatively poor catalysts.

With the aid of all of the foregoing facts and conceptions it should be possible to trace what may be called the life history of a sulphate or of a number of sulphates in the roasting furnace. While, owing to the complexity of conditions and reactions within the furnace, nothing better than general statements can be made, the picture thus produced may be of some value in making clear the principles that govern the reactions.

As it is frequently conducted the process of roasting is a slow one, the cold, granular material being introduced into the furnace and having its temperature gradually raised by being advanced from the cooler to the hotter portions. In certain processes of blast roasting this procedure is not followed, and consequently this discussion does not necessarily apply to these cases. As the temperature of the ore is increased the water is expelled, and the sulphides are ignited, the ignition temperature varying with different sulphides and depending to some extent upon the grain size.

Of the sulphides commonly present in the furnace pyrite is probably ignited at as low a temperature as any. Hence at comparatively early stages of the roast the oxidation of pyrite is started, with the production of sulphur dioxide and ferric oxide or the magnetic iron oxide. In the interstices of the ore bed sulphur dioxide is produced by the partial union of the oxygen with the sulphides, and here the conditions are favorable to the production of sulphur trioxide. The temperature is comparatively low; sulphur dioxide and oxygen are mixed together in the presence of iron oxide and other catalysts; the formation of sulphur trioxide is a natural consequence of these conditions. At the low temperature prevailing the dissociation tension of ferric sulphate may be less than the partial pressure of sulphur trioxide that has been produced, and a part of the ferric oxide is sulphatized.

Then the reactions occurring in the ore bed are disturbed by the passage of a rabble, which exposes at the surface of the bed many grains that have hitherto been underneath and buries others that have been on the surface. Also the material, as a whole, is advanced toward regions of higher temperature. As a result of the stirring the ferric sulphate that has been brought to the surface, being exposed to direct contact with the furnace gas, may begin to dissociate. Similarly the iron oxide that has been formed at the surface of the ore bed, upon being buried and placed in an atmosphere comparatively rich in sulphur trioxide, may become sulphatized.

With rising temperature other sulphides are ignited, producing metal oxides and sulphur dioxide, from which the corresponding sulphates may result by processes similar to that of the formation of ferric sulphate. In these processes ferric oxide doubtless plays an important part in catalyzing the reaction by which sulphur trioxide is produced.

It has been previously noted that the dissociation tension of ferric sulphate increases more rapidly with temperature than is the case with the other sulphates. Therefore, while the ferric sulphate is readily formed during the earlier stages of the roast, the advancement of the ore to regions of higher temperature will rapidly increase the dissociation tension of this compound The sulphur trioxide tension thus maintained in the interstices of the ore bed will aid in the sulphatization of other oxides.

The action of ferric sulphate in sulphatizing other oxides by its own dissociation is, of course, not peculiar to this compound alone. Other sulphates in their turn will dissociate and assist in the formation of still other compounds of lower dissociation tension.

When mixtures of several oxides are present in the ore bed at one time, the order of sulphate formation will in general be the reverse of the order of magnitude of the dissociation tensions of the corresponding sulphates at the prevailing temperatures, i.e., the sulphate of lowest dissociation tension will form first. However, it cannot be said that the order of sulphate formation in the roasting furnace is strictly in accord with this principle, because to have sulphates formed there must first be oxides, and the ignition temperatures of the sulphides determine to some extent the temperatures at which the various oxides will appear.

An oxide that may combine with sulphur trioxide to form a basic sulphate as well as the normal sulphate will first be converted into the basic compound, which in turn may be converted into the normal compound. This is true because the basic sulphate has in general the lower dissociation tension of the two.

In considering the question of sulphate formation in the roasting furnace the important part played by catalysts, notably ferric oxide, must be remembered. These substances accelerate at low temperatures the oxidation of sulphur dioxide and thus aid in establishing relatively high concentrations of sulphur trioxide within the interstices of the ore bed. It is here, if

anywhere, that favorable sulphatizing conditions are to be found; the surface of the ore bed, being in direct contact with the furnace gases, is not a region in which the formation of sulphates is to be expected, under the ordinary conditions of roasting.

It is not to be inferred from the foregoing that there is a definite order in which the metal sulphates make their appearance in the roasting furnace and that each sulphate must be formed and then decomposed before the next of the series is produced. Nothing could be further from the truth than this idea. Sulphates may begin to form in roasting as soon as their corresponding oxides are produced, provided sulphur dioxide and oxygen are present to produce by their combination the necessary sulphur trioxide. The condition necessary for sulphate formation is that the dissociation tension of the sulphate be less than the existing partial pressure of sulphur trioxide.

This condition is most likely to occur in the deeper portions of the ore bed.

The reverse of this condition will produce the dissociation of the sulphate, and conditions tending to produce dissociation are to be expected at the upper surface of the ore bed.

Bearing in mind the fact that the ore is generally stirred to a greater or less extent, it should be evident that at no time can a single oxide monopolize all of the sulphur trioxide in any part of the furnace, and, therefore, that many sulphates may be formed and decomposed at the same time. This statement includes no consideration of the rate of formation and decomposition of the various sulphates; that is quite another matter and has been discussed at some length in a previous paragraph.

As the ore is advanced in the furnace and its temperature is increased the dissociation tensions of the various sulphates that have been formed increase, and their tendency toward dissociation increases accordingly. The rates of dissociation, when the sulphates are brought to the surface of the ore bed by rabbling, are thus accelerated; and, in addition to this, increasing temperature tends to reduce the partial pressure of sulphur trioxide maintained within the interstices of the ore bed by shifting the equilibrium of the sulphur dioxide, oxygen and sulphur trioxide system. Thus the partial pressure of sulphur trioxide in these spaces may be reduced below the dissociation tensions of many of the sulphates, and at elevated temperatures even in the deeper portions of the ore bed sulphates may undergo decomposition at a fair rate. At this stage the presence of the iron oxide and other catalysts is of great assistance in aiding the dissociation of sulphur trioxide, thus accelerating the dissociation of the sulphates. Therefore, at high temperatures ferric oxide is of assistance in the dissociation of the same sulphates that are formed by its aid at lower temperatures. Since, as has been already pointed out, the basic sulphates have in general lower dissociation tensions than their corresponding normal compounds, the former will persist at higher temperatures and for a greater time than the latter.

Finally for the complete elimination of sulphur it may in some cases be necessary to produce reactions between various gangue constituents and the remaining sulphates or basic sulphates. By this means the sulphur trioxide is liberated and such compounds as silicates and ferrites are formed, with or without complete fusion of the roasted material.

Correction: In the first part of this article, published in the April issue, on page 222, in the seventh line of the first column the word absorption should read adsorption.

Department of Metallurgy,
The Pennsylvania State College,
State College, Pa.

Flotation in Gold Metallurgy*

BY W. B. BLYTH

The application of flotation to the concentration of gold ores is only a question of time. Already plants have been erected in this connection, and operated (so it is said) successfully.

In the first place, being a concentration process, it is of value only where the valuable constituents of the ore are in the mineral, or when some refractory mineral is present in an otherwise free-milling ore, and it is desired to remove that mineral subsequent to cyanidation. In this latter connection the flotation process seems to have an extended field of usefulness in the preliminary concentration of cupriferous gold ores. These have been a bugbear to metallurgists for many years—not because the copper interferes with the dissolution of the gold, but because it consumes so much cyanide during the process. A very small percentage of chalcopyrite will render the treatment of a low-grade gold ore unprofitable under existing conditions. The flotation process will remove the copper in the form of a marketable concentrate, and will do it cleanly and at small cost. The remaining pulp will be in a fit state to undergo ordinary cyanide treatment.

It is doubtful if it will ever pay to float mineral from an ore that yields its gold readily in an all-sliming process. It must be remembered in this case that the mineral that is slimed in a circulating cyanide solution during crushing will yield its gold by simple, inexpensive agitation. The coarse mineral can be removed, classified, and slimed in the usual manner, and the slimed product mixed again with the rest of the pulp prior to agitation. If the mineral is floated off, then the same ultimate procedure must be adopted with the floated portion. The additional expense of flotation will be incurred, as against the cost of agitation and filtration of a large proportion of more or less barren tailing. The latter will generally be found cheaper.

When studying the features of roasting refractory floated concentrate prior to cyanidation, it must be remembered that the standard flotation process is particularly efficacious in floating mineral slime. As tables do such excellent and cheap work in separating out the coarse mineral, it may be said that, as regards gold ores, the chief field for flotation lies in the concentration of refractory slimes.

It must be borne in mind that the roasting of slimes from a cyanidation standpoint is a difficult problem, and one that, as far as the writer is aware, has never been solved. The process of drying slimes leaves lumps, and these, however small, will never roast perfectly sweet.

Filter-pressing and air-drying, followed by disintegration of the concentrate prior to roasting, might get over the difficulty. The writer, however, would emphasize that it is a problem in itself, and warns investigators that the mere fact of being able to successfully float the values from a mineralized slime does not indicate that it can be successfully treated unless there is a smelter handy to buy the concentrate.

In many cases in Western Australia the mineral constituents of the ores are so fine, and so intimately mixed with the gangue that the whole ore must be reduced to a colloidal slime before the mineral is liberated. When liberated, the mineral in this class of ore can be readily floated. Kalgoorlie ore, worth 40s. a ton, can be readily reduced to 3s., with the production of from 10 per cent to 15 per cent of concentrate, in this manner. The expense of reducing to colloidal slime, however, is very great, and this, as well as the question of the subsequent roasting prior to cyaniding of the floated slimed concentrates, is not particularly attractive.

*Aust. Inst. Min. Eng., *Bulletin* 16.

The Cyanamid Process*

BY FRANK S. WASHBURN

The fixation of atmospheric nitrogen has had commercial application for the past ten years. During this period different types of processes have been conceived; four, the Serpek, Haber, arc and cyanamid, have seriously attempted commercial exploitation; two, the arc and cyanamid processes, have proved to be commercially practicable in the broad sense. Of these two the latter may justly claim to be of great economic importance to the world because the unit of fixed nitrogen in its first product is capable of being more cheaply produced than by any other present-known process, and because this first product has a direct and valuable use of itself and constitutes the raw material for a varied and important line of derivatives into which, for the most part, it can be cheaply transformed.

The annual productive capacity of the existing plants employing the arc and cyanamid processes is between 90,000 and 100,000 net tons of fixed nitrogen, which, at the normal average value of the product at the factory door, represents $25,000,000. This is divided in the ratio of two-thirds to cyanamid and one-third to the arc process. The American Cyanamid Company's factory at Niagara Falls, Canada, has alone a capacity in fixed nitrogen approximately half as great as the total world's installed capacity by the arc processes.

More than 3000 technical articles dealing with almost every conceivable phase of nitrogen fixation have appeared in different languages. The patents applying to the subject in all its branches number into the thousands. So far as the author of this paper knows, nothing has appeared in the nature of a differentiation of processes based on the economics of the world demand for nitrogen. It is only for a limited developmental period that the theoretical, technical advantages and limitations of related processes constitute a practical basis for hazarding opinions as to their ultimate commercial value. It is also true that until an art has had some years of commercial application it is impossible to analyze and draw sound conclusions from the economics of the situation, the final arbiter in determining the social value of any process.

The art of atmospheric nitrogen fixation is now old enough to enable one to see the economic aspects of the case, and therefore, in casting about to determine what part of this vast subject to deal with in this paper, the author thought it would be of interest and possibly of value to treat herein the broad commercial outlook for the various fixation processes, and in order to limit the matter to conditions more or less well known to all of us, conditions on the North American continent, for the most part, will be the only ones considered.

Two nitrogenous compounds, nitrate of soda and sulphate of ammonia, constitute in value 80 to 85 per cent of the total raw nitrogen compounds produced throughout the world. The value of their combined production in 1913 was between $190,000,000 and $200,000,000. It is estimated that 80 per cent went to agriculture, corresponding to an annual per capita tax on the 600,000,000 inhabitants of the earth of thirty-three cents.

Nitrogen has four main uses: as an agricultural fertilizer, as nitric acid and derivatives therefrom, as ammonia, and in dyes and various other chemical compounds. Measured in the quantity of contained nitrogen, and in view of the restricted opportunities in the United States for immediately developing the chemical and dye industries on a large scale, we need consider as bearing decisively on atmospheric nitrogen fixation processes only the three first-mentioned uses, namely, for crop fertilizer, for nitric acid and its derivatives, and for ammonia as such.

The farmers' purchases in nitrogen used east of the Mississippi River last year approximated $75,000,000. More than 90 per cent of fertilizer nitrogen is in the form of ammonia. The normal annual consumption of nitric acid in the same region is about $7,000,000. The price paid per unit of nitrogen is about the same for each, and the percentage annual increment of consumption is about 10 per cent in each case. However, the importance of the fertilizer field in comparison with the nitric acid field, in their bearing on the fixation of atmospheric nitrogen, is not fully nor even approximately measured by this ratio of ten to one.

The use of nitric acid is along established lines looking comfortably to the future for a steady growth, with no serious limitations hampering modest development and no great unsatisfied human need demanding great development. It is essentially a small business as great industries go. The fertilizer industry has a very different significance. The population of the United States from 1900 to 1910 grew from 76,000,000 to 92,000,000, an increase of 21 per cent. Crop production increased 10 per cent in the same period. Exports of wheat and flour decreased from 31 per cent of their production to 13 per cent. The importation of foodstuffs and live animals practically doubled, while imported manufactured foodstuffs more than doubled. Beef cattle production fell off 32 per cent as the population increased 21 per cent. These figures are strikingly reflected in the increased cost of foodstuffs, which from 1896 to 1912 amounted to 80 per cent in the United States, while the general advancement in the cost of living during this period was 59 per cent in the United States, 40 per cent in England, and 40 to 45 per cent in continental Europe.

These facts point to the necessity of increasing crop yields without additional labor—and that defines fertilizer. European yields per acre cultivated are 50 to 100 per cent greater than American yields. The use of fertilizer in Europe, per acre cultivated, is enormously greater than in America. The average increase in yield in Germany for the past twenty years has been approximately 60 per cent, in the United States 20 per cent. Abroad this increase is attributed to intensive farming, better selection of seed, the rotation of crops and, to the extent of 50 to 70 per cent of the increase, to the use of commercial fertilizers.

The farmers' purchases of fertilizer in the United States last year in nitrogen and phosphorus constituents (later it will be shown why both are here included) was approximately $150,000,000. Were the cultivated lands east of the Mississippi to receive for each of two years out of every three the quantity of fertilizer normally used per acre each year in Germany, the bill would have been approximately $1,600,000,000, or ten times as great as the actual expenditure. The very limited use of fertilizers in the United States does not arise from the possibility that fertilizers do not pay. Indiana experiments, conducted in ten counties, produced an average increase of 11.6 bu. of wheat per acre, valued at $11.60, for an expenditure of $3.67. An instance of a very low return in the use of fertilizers is an unpublished record of thirty-seven experiments in Illinois in 1913, showing an average increase of 5.2 bu. of wheat, valued at double what the fertilizer cost.

The fertilizer industry to-day suffers many handicaps. These originate in part from the farmer's limited capital for properly conducting his business, his lack of knowledge which closes to him what would otherwise

*A paper presented April 23, 1915, at the Atlantic City meeting of the American Electrochemical Society for general discussion, having been previously read at a joint meeting on March 12, in New York City, in a joint meeting of the American Institute of Electrical Engineers and the New York section of the American Electrochemical Society.

be avenues of advancement and prosperity, and in part also from the fact that there is no vital, broadcast propaganda and educational bureau conducted by the fertilizer industry itself.

The greatest handicap is possibly in the material used. The industry is carried on by collecting at a great number of places throughout the agricultural regions east of the Mississippi a great variety of materials, each containing some one of the so-called plant foods, namely, nitrogen, phosphorus and potash, the last representing only about 10 per cent of the total. For the most part these materials are low in fertilizing value, and when mixed in a manner to include the low as well as the high-priced materials, there results of necessity a product of which 85 to 90 per cent is useless dead weight, only the small remainder having fertilizer value. Forty per cent of the annual fertilizer product in value is in the nitrogen constituent drawn from materials that are either by-products or wastes, such as sulphate of ammonia, slaughter-house refuse, fish scrap, vegetable refuse, waste of sugar works and distilleries, hair, leather, wool, hoofs and horns. The phosphoric acid constituent is secured from acid phosphate analyzing from 14 to 16 per cent P_2O_5, and as a general rule constituting one-half of the complete fertilizer mixture. Few of these raw materials in the broad sense are satisfactory. They are borne with because up to the present time there are no others commercially available. They pay the uttermost limit in the way of transportation charges to the point of their preparation, and after being mixed they bear a further great transportation burden to the consumer's railway station. There is a relatively large expense for mixing, storing, drying, bagging and selling. After the farmer has received his goods at the railway station, he must haul over spring roads, often almost impassable, 1,000 pounds of material in order to get 150 pounds of plant food. It is one of the recognized, recurring, contributing causes for small crops, particularly in the South, that the roads are so bad in the spring, due to rains, that farmers cannot haul the necessary amount of fertilizer.

Notwithstanding the consumer pays for nondescript materials, requiring only to be mixed in the crudest manner, a price 60 per cent greater than their spot value, the fertilizer industry as a whole, which prepares and sells the product, is conducted without measurable profit.

Unless revolutionary developments in some vital respect come to the aid of this great industry in the United States, any marked improvement is impracticable. It would appear, for reasons already set forth, that possibly the matter of greatest economic importance in the United States to-day is that conditions shall be brought about by which the farmer will use a vastly greater quantity of fertilizer than is now used. We believe the most important single contribution to this end would be a high-grade chemical salt containing nitrogen and phosphorus, well balanced and in large percentages, and possessing in a high degree the many requisites of a good fertilizer, such as being non-hygroscopic, non-toxic, finely granular in form, non-leachable in the soil and readily convertible by nature's forces into the organism of the plant. The process for the fixation of atmospheric nitrogen that will contribute the nitrogen content to such a fertilizer compound to the greatest net advantage may be justly viewed as the most important, not only to society, but also therefore to those who exploit it.

Discussions of the ultimate commercial superiority of the favorite process and the consequent complete annihilation of every other have been almost interminable. These have proceeded apart from any broad conception of time, place, the demands of mankind or the quantitative application of the product. They generally take the form of rival claims for cheapness in the cost of production, and this without much reference as to whether the unit cost applied to a form of nitrogen for which there was any particular or large demand, and without reference to whether the product was to be produced at a place and in a form enabling it to be transported to the consumer.

The Serpek process was discussed by volunteer adherents without knowledge that per unit of nitrogen fixed the necessary expenditure of heat energy from electricity alone is as great as the total electric energy consumption in cyanamid. Therefore, no suspicion was aroused that possibly nature had not placed the necessary raw material, bauxite, within practicable shipping distance of equally necessary cheap water powers. The limitations of the by-product, upon which the commercial possibilities of the process depend, were not questioned either as to the difficulties in converting it to commercial aluminum or as to the relation of its volume to the market demand for the metal.

The Haber process has been taken by the public for granted as one practicable of universal application because of its large though single use by a great concern of brilliant accomplishments in the commercial chemical world. The public does not know of the pressing problem of disposing of great quantities of sulphuric acid, and the single problem involved of how, under the local conditions, to devise the cheapest possible means of providing the requisite ammonia for using the acid in sulphate of ammonia. The electric energy necessary to the process is generally considered negligible, and yet a proposal to establish a plant close to New York involved, at the necessary power cost in that vicinity, as great an expense for electric power as the total power cost for cyanamid in an available site then under consideration for that process.

Air nitrogen fixation processes divide themselves into two broad classes, namely, those that come in at the nitric acid end, and those that come in at the other extreme, the ammonia end. There is no expectation that the various "arc" processes producing nitric acid will ever have employment in the production of ammonia compounds, for the sufficient reason that there is no prospect of ever being able to commercially convert nitric acid to ammonia. Therefore, the best that can be said of the "arc" processes is that they may be able by reason of having nitric acid as their first product, to occupy exclusively the field for the production of nitric acid. We have already seen that this field is not only relatively but absolutely a limited one for the present, as it is prospectively for the future.

The "ammonia" processes are not ready to admit, however, that there is an insurmountable barrier separating them from the nitric acid field. A tried, thoroughly workable, commercial plant for the oxidation of ammonia into nitric acid is not yet complete and in entirely satisfactory operation, but, on the other hand, the various steps necessary to the operation of such a plant have been separately brought to such stages of development as to leave no doubt in the minds of the experienced men who have worked upon the problem of the ultimate complete commercial practicability of carrying the ammonia processes for the fixation of atmospheric nitrogen through to the nitric acid producing stage.

A powerful factor operating as a disadvantage in the "arc" processes to the manufacture of nitric acid is the extraordinary difficulty of transporting the acid from the remote, cheaply developed water powers, very limited in number, where alone these processes can be employed, to the place of use for the acid, both sea and rail transportation being practically invariably

necessary. This audience does not need to be told how serious a matter is this. The nitrate compounds made from acid produced by the "arc" processes have found no place as a fertilizer in this country. Nitrate of lime, even in the so-called basic form, is too strongly hygroscopic to permit its use alone or as part of a mixture to be used through the ordinary drills by which fertilizer is distributed to the soil in this country. Even if the physical form were entirely satisfactory, it could not satisfactorily have a very large place in fertilizer mixtures in this country because of its being too readily available in the soil and because the valuable form of fertilizer nitrogen is as ammonia and not as nitrate. We have seen furthermore that the fertilizer industry demands something more than a new nitrogenous material, however meritorious it may be, merely as an additional one to the many which now constitute a part of a complete fertilizer mixture.

For a time it was thought that the treatment of phosphate rock by nitric acid might possibly find a large place in the fertilizer world. Two decisively unfavorable and irremedial results have developed from this attempt; first, the product is excessively hygroscopic, the surface when exposed taking up sufficient moisture to reduce the external parts to a molasses-like condition, and second, the content in plant food, approximately 11 per cent nitrogen and 14 per cent phosphoric acid, is markedly lower than that readily securable in the new commercial ammonium phosphate compounds resulting from the combining of ammonia and phosphoric acid. When carried to the monocalcic stage, thereby giving it the desired water solubility, the excess acid is of necessity so great that the crop is burned and destroyed. Much money has been spent on these efforts, which have always resulted in failure.

This brings us now to the consideration of the practicability of an ammonia phosphoric acid compound for agricultural use. The mono-ammonium phosphate, containing theoretically 14.6 per cent of ammonia and 61.3 per cent of phosphoric acid (P_2O_5) and the di-ammonium phosphate, containing theoretically 21.8 per cent of ammonia and 53.4 per cent of phosphoric acid, have been recognized by the scientific world for many years as fertilizers of extraordinary value, being in effect perfect materials, as they possess every qualification of a good fertilizer. The manufactured product made in this country has not developed any limitation. Under some circumstances, at least, the results in crop increase are greater per unit of ammonia and phosphoric acid than is securable from any other fertilizer or fertilizer compound, and the question has arisen whether this salt may not produce its result partially from the exercise of the same natural laws that apply to the action of manganese sulphate, for instance, in which there is a crop increase that cannot be attributed to the taking up by the plant of anything contained in the fertilizer. The effect may some day be safely attributed to the inducement that the salt has given to increased activity of the chlorophyl and thereby increased power of assimilation on the part of the plant.

The commercial ammonium phosphate product may be readily produced at will with varying proportions of ammonia and phosphoric acid, ranging from 13 and 47 to 21 and 46 per cent respectively. Thus it is that the plant food constituents of this single material, varying between 60 and 67 per cent, occupy the entire range of the usually desired relationship between ammonia and phosphoric acid. The phosphoric acid content of the commercial acid phosphate now used in agriculture, a product which, roughly speaking, results from pouring a ton of 52 deg. sulphuric acid on a ton of rock containing 30 to 32 per cent P_2O_5, contains about 14 to 16 per cent P_2O_5. In value it constitutes about one-half the farmer's fertilizer bill in the United States each year. Whatever advantages a new kind of phosphoric-acid-containing material may have, it should be capable of being produced at a cost no greater than the per cent unit cost of phosphoric acid in acid phosphate.

Two methods of manufacturing ammonium phosphate compounds have been developed. One of these is in the proved commercial stage and can produce as cheaply, at least, as by acid phosphate. The other is in the advanced developmental stage and promises still cheaper production costs. The first is applicable wherever cheap sulphuric acid may be had, and the second, which employs the electric furnace in driving off phosphorus from the phosphate rock, is applicable only where there is cheap water power available.

When the problem is referred to the actual conditions existing on the North American continent, the most available process known for providing agriculture in a broad way with the ammonia constituent of an ammonium phosphate compound is the "cyanamid" process. Searching investigation and analysis, for four years, of prospective cyanamid manufacturing sites, covering the United States and Canada, has developed a state of facts establishing the practicability of placing ammonia at the disposal of agriculture and the arts in practically every place of large use in the United States, and cheaper and simpler than could be accomplished in any other way. This may be done by shipment of cyanamid from a central point of manufacture to these various localities and its conversion there into ammonia.

These natural tendencies toward the "cyanamid" process as the principal source for nitrogen supply might be turned aside, however, unless that material and its important derivatives, notably ammonia, could be produced and delivered to the consumer cheaper than by other means and through the employment of capital in such a manner as would induce the investment of money in the undertaking. This brings us then to a consideration of the costs of production applied to a distinctive set of conditions which correspond not only with all the important conditions surrounding the demand for and use of the product but also those which characterize an actual place of production and its geographical relation to the consumer.

There is properly a hesitancy on the part of any business enterprise to disclose actual costs. Such information is frequently made wrong use of, and the risk involved in making it public is wholly out of proportion to the gain. At the same time the author realizes that without volunteering exact statements of comparative cost figures, open to confirmation or refutation, as the case may be, it is difficult to carry conviction to the hearer that one's conclusions are sound. The founders of the American Cyanamid Company have not from the beginning been wedded to any particular process for the fixation of atmospheric nitrogen. The aim and policy have been to conduct the company's activities and research work toward the end of developing a great nitrogen industry. It has investigated many processes with the conviction that it could not hope to have permanent and ultimate success except through the application of the best. Its research work in entirely new fields, and in the regular manufacture of its product, has been practically continuous from the day it first began commercial operations in 1910. It is therefore natural that those connected with the company should feel confident of their judgment on many matters bearing upon the relative merits and limitations of various nitrogen fixation processes.

Therefore, while it may be impolitic to disclose actually attained minimum costs it may be possible to establish particular facts and comparisons which will by

their logic carry conviction as to the order of compared processes so far as production costs are concerned, without, however, expressing the exact differences in costs. For instance, by the "arc" process the factory cost of nitrogen in commercial nitric acid, excluding all power costs (derived by applying actual working records to a particular manufacturing site where all conditions are of the most favorable nature) is greater than the total cost of nitrogen in "cyanamid," including power at $10 per continuous horsepower per annum (at a site where raw materials and labor are relatively high). Furthermore, taking that particular "arc" process which is the lowest in power consumption, the power cost alone, at eight to ten dollars per continuous horsepower per annum in weak nitric acid is greater than the total cost of "cyanamid," including power at the same cost per horsepower per annum (and at a site where raw materials and labor are high). These are actual comparisons and lead conclusively to some irrefutable deductions: first, that the "cyanamid" process can fix nitrogen cheaper than the cheapest of the "arc" processes, even although a charge of ten dollars per continuous horsepower per annum is made against "cyanamid" and the power is given free to the "arc" process; second, if the cheapest of the "arc" processes, so far as power consumption is concerned, is charged only with power at the rate of eight to ten dollars per continuous horsepower per annum and the process is presented without cost or charge of any sort with all labor, raw materials and supplies, its unit of nitrogen would cost more than the total cost of the unit of nitrogen by the "cyanamid" process. It also follows from these conditions that the total cost of the unit of nitrogen in commercial nitric acid made by the "arc" process cannot by any chance be less than double the total cost of the unit of nitrogen in cyanamid made by the "cyanamid" process. We have seen that the really great application of nitrogen is at the ammonia end and these comparisons are impressive in showing not only that there is no hope of the "arc" process working into ammonia production but also, and what is of more importance, that the "cyanamid" process has to its credit a wide margin of saving in cost to span the gulf between "cyanamid" and nitric acid.

The first step in the derivation of nitric acid from cyanamid is to convert the latter into dry ammonia gas. Such conversion is now conducted in so many places and on so large a scale that the actual cost of the operation, including all losses, is no longer a matter of speculation or approximation. The efficiency has been raised in actual practice to over 99 per cent and the cost, while not negligible, is so low as to add only a small percentage to the ordinary cost of the unit of nitrogen in "cyanamid." Therefore, the facts just set forth as to the cost of the unit of nitrogen in "arc" process nitric acid, compared with the cost of the unit of nitrogen in cyanamid, apply as well to the cost of the unit of nitrogen in pure ammonia gas. Roughly speaking, therefore, there is to the credit of the ammonia, available for oxidizing it to weak nitric acid, fully one-half the cost of weak nitric acid derived by the "arc" process. As a matter of fact the indications are that this span will be bridged by the absorption of not more than one-half this difference, making weak nitric acid by the "cyanamid" process cost approximately three-quarters of the "arc" process. As power is brought below ten dollars per continuous horse-power per annum, production costs by the "arc" processes approach more nearly to costs by the "cyanamid" process. It is possible to make the general statement that the costs per unit of nitrogen in weak nitric acid may be taken as the same for both processes where power costs about $4 per continuous horse-power year.

Comparison of the costs of ammonia gas by the "cyanamid" process and the "Haber" process show, broadly speaking, that the Haber process in its most favorable environment involves a cost nearly double that of the "cyanamid" process under favorable conditions practicable of attainment.

It must not be understood that the "cyanamid" process has exhausted the possibilities of further economies in manufacture. As examples, in one new factory study in which the requisite coke is to be made by local by-product ovens, the operations so balance that the fuel gas derived is the quantity required, and as the tar and ammonia products pay for the coking, the coke is had at the price of coal. Where ammonia is derived at the cyanamid factory the sludge from the autoclaves composed of calcium carbonate and carbon may be turned back through the carbid furnaces and maintained in the cycle practically indefinitely as a carrier of nitrogen.

However, the whole story is not involved in a study of production costs, for there are other factors which may have a deciding voice, and of these we may mention as important the amount of the necessary investment for a given output, the salvage in the case of ultimate abandonment, the ratio of interest charge to the out-of-pocket expense, bearing in mind that the latter may be very much reduced by improved operating means while the former is fixed for all time. Taking the necessary investment in the "arc" process per unit of nitrogen in weak nitric acid as a basis, and assuming power to be placed upon the switchboard at an investment cost of $50 to $75 per horse-power, the corresponding investment in the "cyanamid" process for a unit of nitrogen in weak nitric acid would be about one-half, and as cyanamid or ammonia gas about one-third. It is believed that the Haber process in the United States on the same basis would involve an investment of about two-thirds to three-fourths of the "arc" process. In the contemplation of any enterprise requiring large fixed capital there is a reasonable amount of capital beyond which objections to an increased amount are not to be measured by applying the interest and amortization rate to the estimated costs of production. Converting a vast amount of gold in the bank into bricks and mortar, special machinery and appurtenances, particularly in the application of a new and special art is a serious risk for which there is no exact measure, but which in contemplating the risk should weigh heavily as a guide to judgment.

In the case of ammonia production by the "cyanamid" process the fixed investment may be as low as one and one-half times the annual value of the product and in the case of the Haber process three times. In the case of nitric acid by the "cyanamid" process the investment may be as low as one and one-fourth times the annual value of the product and in the case of the "arc" process with a power investment of $75 per continuous horse-power the fixed investment would be between three and four times the market value of the annual product.

The majority of manufacturing concerns in the United States vary in fixed investment from one to one and one-half times the value of the annual product and the inherent risk in industrial enterprises, for reasonably assured profits demand, for the most part, very special conditions where this proportion is exceeded. Even that class of investments considered most stable as to reliability, permanency and growth, namely, public utility corporations, do not exceed $4 to $6 investment per dollar gross revenue. We are therefore met in the case of the Haber and arc processes with the necessity for making an investment which, in the judgment and practice of the industrial world, is wholly out

of proportion to the market value of the annual product, while in the case of cyanamid the requirements are within the limits of ordinary commercial practice.

These considerations serve to emphasize the difficulties in commercially advancing any new enterprise. The younger technical men do not encounter these difficulties and therefore do not give them due weight. There is extraordinary difficulty, particularly in the United States, in financing a new chemical enterprise, particularly if it involves a large preliminary expenditure in research and developmental work. The banker's attitude, and properly so, is to compare assets and liabilities. Buildings, equipment and manufacturing sites are acceptable assets notwithstanding that in many companies if the business itself were abandoned there would be little or no value in the physical properties. Knowledge, processes, and ideas are not impressive assets. They are considered in large part to have been something secured at great cost, but, even with good patent protection, practically available for the use of prospective competitors without cost to them. In some other countries such enterprises are viewed quite differently, notably in Germany, where ideas are the foundation of great and profitable enterprises and where by law and practice they are better protected for the exclusive use of those who have developed them than in this country.

The promise, or even the assurance of reasonable profit, is seldom a sufficient inducement to the investor to undertake a pioneer enterprise. The competitive element which dominates almost every other activity is lost sight of by the amateur promoter. He forgets that to the mind of the prospective investor he is in the sharpest kind of competition with those presenting other types and kinds of enterprises demanding capital. His project must grip the imagination with peculiar attractiveness as well as impress the practical sense of those to whom it is brought as not only being prospectively profitable but also assuredly safe with a minimum prospect of loss and a maximum prospect of profit. Of the many subordinate advantages there may be specifically mentioned an early dividend paying period, a ready market for the securities, their acceptance as good collateral, and a ground-floor prospect in future extensions. In the end it must outweigh, in some cases, literally scores of other projects all claiming equal if not superior merit in every particular. There is another consideration of kindred merit which will be impressive if one considers that in a thing so extensively engaged in as trade in securities, one of the very largest activities in which mankind interests itself, there must grow up inevitably certain more or less arbitrary rules, practices and points of view. These all turn naturally upon the usual thing, and the usual thing is the established industry, or at least an enterprise engaged in an established industry. Therefore, the new thing has a slow and difficult road to travel and its difficulties are more than in direct proportion to the amount of capital demanded. Those fixation processes which employ and own their own water powers make a plea to capital that others cannot make, for the reason that it can generally be shown that should unexpected competitive developments in the remote future drive the undertaking to an unreasonably low return upon the investment, the rental value of the water powers for other purposes will probably insure the continuance of a satisfactory return upon the total investment.

Even if it were granted that the "cyanamid" process is prospectively to play the leading rôle in the fixation of atmospheric nitrogen so far as the most important use of nitrogen is concerned, namely, in agricultural fertilizers, and even if it were further granted that it is the logical source of nitric acid, the question may still be an important one as to whether the raw product of this process may be looked to as the source of a long and important line of nitrogen derivatives. The fact is that there is an almost interminable line of derivatives which can be produced from cyanamid with the greatest technical success and assurance and their manufacture has proved to be in some cases commercially feasible. The direct and valuable application of the raw product, cyanamid, is unique in air nitrogen fixation processes. The proof of this value lies in the fact that fully 80 per cent of the entire annual product of normally $15,000,000 value is sold as the raw product.

The principal derivative at the present time is ammonia, which has earlier herein been referred to. None is being made in America at this time outside of the Cyanamid company's research laboratory, but abroad various plants are producing some 15 tons of gas per day, part of which goes into high-grade sulphate for fertilizer use and part into anhydrous ammonia. There is also installed and about ready for operation a large Norwegian plant erected for the Birkeland and Eyde interests for transforming some 60 tons of cyanamid per day into ammonia, which will be absorbed in nitric acid for the production of ammonium nitrate. The transformation takes place according to the following reaction:

$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$$

This decomposition is accomplished by the use of water and high-pressure steam in autoclaves, and large-scale working plants show an efficiency of over ninety-nine per cent nitrogen transformation. The ammonia gas is delivered from the autoclaves mixed with steam and absorbed directly in sulphuric acid without removal of the steam, or passed through a very small ammonia column equipped with condensers and coolers for the removal of the steam, thereby yielding a very high-grade pure ammonia gas. In case it is desired to make anhydrous ammonia it is simply necessary to intensify this drying action and compress the gas; considerable quantities of this ammonia are sold in France in the anhydrous state. The cost of the transformation is almost negligible, as the units have very large capacity and require very little attention.

Cyanamid in the presence of water tends to transform itself slowly to dicyandiamid, and this latter to urea. Methods have been recently evolved which make practicable these transformations either to urea or dicyandiamid with approximately 90 per cent efficiency and obtain chemically pure salts as the end product. Dicyandiamid, formula H_2CN_2, contains 66.6 per cent nitrogen, or probably the highest concentration of any staple nitrogen compound. It has been proposed for use in explosives, acting as a deterrent, also for use in the dye industry. Its greatest future possibly lies in the ease with which acids transform it into the guanidines, which should find large uses in the explosive industry. The material has been proposed for use as a fertilizer because of its high nitrogen content, but it is probable that its slow decomposition in the soil will never warrant its use for this purpose.

The United States is importing about $50,000 worth of high-grade urea annually for the celluloid industry alone, and could this material be cheaply produced there is no doubt but that it would find an even greater use in the explosive industry. Considerable quantities of this material have been produced in the research laboratory, which has been tried by the celluloid manufacturers with perfect success. It is now practicable to replace the importations of this expensive salt.

In the field of organic derivatives of cyanamid there is practically no end to the series that have developed abroad. The latest addition to this group has been

creatin, which seems to be getting somewhere close to synthetic foods.

The calcium in the calcium cyanamid can be replaced by the heavy metals, and recent experimenting with some very interesting compounds, such as lead cyanamid and copper cyanamid, promise valuable results.

When certain grades of cyanamid are melted with common salt the free graphite in the original material is combined with the calcium cyanamid, forming cyanide. A transformation of better than 90 per cent nitrogen efficiency is obtained and the resulting product contains approximately 25 per cent KCN equivalent. This material, which can be prepared so as to deliver it into the hands of the consumer at about two-thirds the present price of high-grade cyanides, requires solution in water and filtration. Both operations are easy, and the filtrate can be used in the place of cyanide for the extraction of precious metals. Large scale experiments have been tried out in various cyanide works throughout the world, and in every case it has proved to be identical in behavior with regular cyanide, showing the same extraction efficiencies. The lower price at which this material can be delivered to the consumer more than takes care of the very simple extra dissolving and filtering operations incident to its use, and there should be, therefore, a very large field for this material, supplanting the more expensive, high-grade cyanides.

Naturally, when the transformation to cyanide is so simple it is also possible to manufacture ferrocyanide, and enter into the case-hardening field and other uses for this material. As a matter of fact, cyanamid itself can be very simply compounded into a case hardener which is the equal of any of the present materials on the market and superior to most of them. The German cyanamid makers have, since the beginning of the war, been swamped with orders for this case-hardening material, sold under the name of "ferrodur."

Reference has been made heretofore in this paper in a general way to nitric acid production from ammonia. There has been developed recently a new process of re-oxidizing ammonia to nitric acid at high efficiency. It is believed to do away with all of the limitations of the Ostwald process and, if so, the industry will be in a position to meet nitric acid demands by way of cyanamid at a cost under conditions existing in the United States below anything any other process can offer. The gases leaving the oxidizing chambers are many times more concentrated than those from the "arc" process furnaces and, therefore, condensation is greatly simplified and recovery much increased. The units can be made large or small and their cost is rather low, so that small nitric acid plants can be installed at almost any place in the country within shipping range of the cyanamid plant, it being autoclaved into ammonia and converted into nitric acid at the point of use.

Quite recently the American Cyanamid Company has been using the "cyanamid" process as a means of producing argon gas in quantities, producing the nitrogen by means of the copper process and later eliminating the nitrogen by continued re-absorption in the cyanamid ovens, leaving argon as the final gas. Thousands of feet of this gas, highly concentrated, is being sold to the lamp industry, chiefly for American use, but in part to consumers abroad.

Atlantic City Meeting of the American Electrochemical Society

The twenty-seventh general meeting of the American Electrochemical Society was held in Atlantic City, N. J., on Thursday and Friday, April 22 and 23, and was concluded in Philadelphia on Saturday, April 24. Since Atlantic City has no local members, the attendance was somewhat less than usual (the number of those who registered being 130), nor was there any official smoker or banquet, but the meeting will be remembered as the one which among the many lively meetings of this society, has produced the most lively and extended discussions, and in the crisp spring air the Atlantic City board walk was enjoyed at its best in spite of an occasional little shower during sessions. When a session closed the sky would clear up.

The hotel headquarters were at the Chalfonte, where all sessions were held.

Thursday Session.—Business Meeting

The annual business meeting was called to order by President Lidbury on Thursday afternoon. The secretary of the society, Dr. Joseph W. Richards, read the annual report of the Board of Directors. The membership at the end of 1914 was 1377 and twenty-nine new members have been elected since the first of the year. Reports of the different committees were then presented and the report of the tellers of election was announced as follows:

Mr. Lawrence Addicks, of Douglas, Ariz., is the new president. Messrs. L. E. Saunders, John A. Mathews and L. Kahlenberg were elected vice-presidents. Messrs. L. D. Vorce, William Acheson Smith and William H. Walker were elected managers. Mr. P. G. Salom was re-elected treasurer, and Dr. Joseph W. Richards of Lehigh University, South Bethlehem, Pa., was re-elected secretary.

Mr. Lawrence Addicks, the new president, was born in Philadelphia, Pa., on March 3, 1878. He was educated at the University of Pennsylvania and at the Massachusetts Institute of Technology from which he graduated in 1899 in both the mechanical and electrical courses. He went to New Mexico, where he was employed in a copper mine, but returned East in 1900 to become assistant to the superintendent at the Raritan Copper Works. In 1905 he became chief engineer and a few months later superintendent of the U. S. Metals Refining Company of Chrome, N. J. He was the superintendent of this copper refinery for nine years. In 1914 he became connected with Phelps, Dodge & Company to conduct the large-scale leaching tests on low-grade copper ore at Douglas, Ariz. Mr. Addicks is recognized as one of the highest authorities on electrolytic copper refining and has presented numerous papers before the American Electrochemical Society, the American Institute of Mining Engineers, the American Institute of Electrical Engineers and other technical and engineering societies.

Presidential Address

The retiring president, F. A. Lidbury, works manager of the Oldbury Electrochemical Company, Niagara Falls, then presented his very able and interesting presidential address on the American Electrochemical Society in Its External Relations, which is published in full on page 277, of this issue.

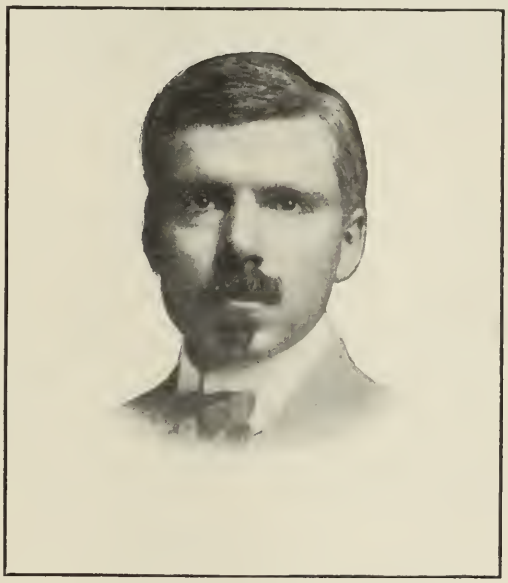
Fibrox

A paper by Dr. **E. W. Weintraub**, of the General Electric Company, Lynn, Mass., deals with the preparation and properties of fibrox, which is the name given by the author to a fibrous material of the composition of silicon oxycarbide. The name is to suggest the remarkable structure of the material. The author first reviews former work done on amorphous silicon oxycarbides by various investigators from Schuetzenberger to Tone and then describes the manufacture as follows:

A muffle (or pot) of material capable of withstanding a temperature of 1400 deg. to 1500 deg. C., having its bottom covered with a layer of silicon pieces, is heated in a gas furnace to the temperature of incipient melting of silicon. A muffle of Dixon graphite clay-lined has proved to be suitable. The ends of the muffle protruding outside the furnace are luted on to the muffle in a gas-tight manner. It is essential that a catalytic agent be used. One such agent is calcium fluoride.

After a run of a few hours the muffle is found filled completely with fibrox, which is removed and the operation repeated. It is only necessary from time to time to break up the slag which forms on the surface of the silicon and to add some fresh fluorspar or other catalyzer.

It is obvious from the process described that fibrox is a product of slow and quiet growth, and from its composition it must be formed when silicon vapors and carbon dioxide or carbon monoxide react. The silicon vapors come from the silicon. The carbon dioxide comes from the combustion gases of the furnace. One has, therefore, to picture to himself the oxide of carbon slowly diffusing through the pores of the vessel and reacting with the silicon vapors. This slow interpenetration of the reacting gases through a permeable wall is an important feature of the process and is essential if the finest structure is to be developed.



LAWRENCE ADDICKS, PRESIDENT
AMERICAN ELECTROCHEMICAL SOCIETY

The fluorspar or other catalyzer used has most probably the function of keeping the slag (silica?) in a sufficiently soft condition to allow the silicon to "seep" through it and expose a clean surface from which the silicon vapors can freely escape.

The most remarkable thing about fibrox is its physical structure. It is a soft, resilient, fibrous material; after general compression it returns to its original shape; it can be cut into plates, sheets, and rings which are self-supporting. The material is an agglomeration of exceedingly fine fibers much thinner than fine hair. The diameter of the fibers is in average about 0.6 micron, or about the wave length of yellow light. Some fibers are undoubtedly smaller and probably approach 0.3 micron.

The apparent density of the material, while varying with the circumstances, is usually between 0.0025 and 0.0030. In other words, it weighs only about 2½ to 3 grams per liter. The real density of the material varies with its composition. When the composition corresponds nearly to the theoretical silicon oxycarbide SiCO (about 21 per cent. of carbon), the real density is 1.84. As the carbon content diminishes the real density increases up to about 2.2 or nearly that of silicon. From the real and apparent density, the actual volume occupied by air is figured out to be over 99.5 per cent. and in the best cases equal to 99.9 per cent. and that of the solid material is only between 0.5 and 0.1 per cent.

For the temperature interval of 100 deg. to 15 deg. a long-fiber dark-green sample of fibrox compressed to a density of 0.767 lb. per cubic foot or 12.3 grams per liter has a resistivity in degrees per watt, per inch cube, $R' = 1675$, or per cm. cube $R = 4200$. A comparison with other materials will be instructive. For wool at a somewhat higher density of 0.955 and the same temperature interval R' (in. cube) = 802 (R/cm. cube = 2000) and at a density of 3.4, $R' = 110$ (R cm. cube = 2700). Wool has to be compressed to a density of 12 pounds per cubic foot or more than 15 times that of fibrox to get the same value of heat resistivity. Eiderdown reaches a value equal to that of fibrox at a density of 5, or more than 6.5 times the density of fibrox. Among the inorganic heat insulators, monox has a density of 6.18, $R' = 1000$ ($R = 2500$) and "Elephant Ear" at a density of 8.4, $R' = 1100$ ($R = 2700$). It will be seen that by its value of heat resistivity fibrox stands in a class by itself. The heat insulating values decrease with higher temperatures. While fibrox is the best heat insulator, it is a relatively good electrical conductor with a conductivity comparable to that of electrolytic solutions. This is most remarkable.

Dr. Weintraub exhibited samples of this most interesting new heat-insulating material. While nothing definite yet can be said concerning the price at which it will be sold, it seems certain that the price will not be prohibitive, as it may be possible to sell the cubic foot at 50 cents, when fibrox is placed on the market.

In the extended discussion which followed Mr. Tone spoke of his own work in this line and said that his silicon oxycarbide differed from fibrox in degree, but not in kind, and Mr. Arthur spoke of similar work done at the Schenectady laboratory of the General Electric Company. Mr. Northrup referred to filtering possibilities and Messrs. Baekeland, Hitchcock, Franklin, Taylor, Mott, Hering, Richards, Frary continued the discussion. While Dr. Weintraub makes fibrox in a gas-fired furnace, Mr. Saunders expressed the opinion that fibrox could be made in an electric furnace.

Thermal Conductivity of Refractories

A paper by Professor **Boyd Dudley, Jr.**, of the Pennsylvania State College, deals with "the methods and results of an investigation designed to develop a practical and reasonably accurate means of determining the thermal conductivity of regular kinds of brick, under conditions approaching those of practice and without the necessity of preparing special shapes or samples of the materials being tested." The author

first gives a classification and review of the various methods which have been devised to measure the heat conductivity of refractories and then describes his own method.

This method of determining thermal conductivities consists of using the brick under test in the construction of one single wall of a specially constructed coke-fired furnace, and measuring the rate of heat flow through a certain area of the test wall by means of a water jacket applied to the cold side. Temperature measurements are made at various points in the brick, and from the data thus secured the conductivity of the material constituting the wall is calculated. The advantages of the method are these: Special shapes or test pieces of the refractory are not needed, the tests being made on samples of commercial brick. The conductivity is readily calculated from the observed data without recourse to complicated factors involving the shape of the conducting body. Variation of the conductivity with temperature is made apparent by graphic representation of the temperature gradient through the brick.

The furnace consists of three permanent walls, one side and two ends, provided with a permanent roof and stack connection. These three walls are constructed of fire brick and tile, and are each 9 inches thick. The roof of the furnace and stack connection are supported from the end walls on iron bars placed as shown. The fourth wall (the front side of the furnace) is independent of the other parts of the furnace and is built of the brick to be tested. The fuel used is sized by-product coke, which is charged through the fire door at the top of the back side of the furnace. The grate consists of four iron bars. Air enters under the grate, and additional air is drawn through openings in the back side of the furnace. These openings may be closed or left open as is necessary; it is found that by regulating the amount of air entering the furnace at the various points it is possible to secure rapid combustion of the coke, from the top of the bed of fuel to the grate, a depth of about 26 inches. In this manner a sufficiently large area of the test wall is heated to a uniform temperature to render permissable the use of a calorimeter 1 foot square.

Concerning the details of the arrangement and especially the construction of the calorimeter with which the rate of heat flow through the wall is measured, the reader is referred to the complete paper to be published in the Transactions of the Society.

The method was applied by the author to tests of four types of refractories. The kinds of brick tested were first-quality fire-clay brick, silica brick with clay bond, silica brick with lime bond and magnesite brick. All were manufactured by the Harbison-Walker Refractories Co., Pittsburgh, Pa.

Details of the composition of the different bricks are given in Table I.

Table I.—Analysis of Brick

Per Cent	Woodland	Quartzite	Star Silica	Magnesite
SiO_2	52.93	73.91	95.85	2.50
Al_2O_3	42.69	22.87	0.88	0.50
Fe_2O_3	1.98	1.48	0.79	7.00
CaO	0.33	0.29	1.80	2.75
MgO	0.38	0.31	0.14	86.50
Alkalies	1.55	1.20	0.39	....
Loss on ignition	....	....	....	0.10
Apparent density	1.91	1.91	1.56	2.46

The results of the measurements of heat conductivities are given in Table II.

Table II.—Heat Conductivities of Brick

Material	Test No.	Exp. Temp. Range	Mean k Over Exp. Range	Calc. k at 100°	Calc. k at 1000°
Woodland	1	120 to 965	0.00676	0.00532	0.00816
Woodland	2	100 to 1025	0.00666	0.00438	0.00880
Woodland	3	400 to 995	0.00704	0.00332	0.00886
Quartzite	1	100 to 935	0.00679	0.00504	0.00880
Quartzite	2	100 to 960	0.00670	0.00521	0.00836
Star silica	1	100 to 910	0.00794	0.00561	0.0108
Magnesite	1	445 to 830	0.0343	.....	0.0343

The third column gives the temperature range in deg. C. for each test. The fourth column gives the mean conductivity k for this temperature range in gram calories per second per inch cube per deg. C. Columns 5 and 6 give calculated values of the heat conductivities k at 100 deg. and 1000 deg. C. respectively.

While the calculated conductivities are in some cases not in close agreement, in general they are consistent in indicating the relative conductivities of the various materials. Taking the averages of the figures applying to each material the conductivities at 100 deg. and 1000 deg. C. are given in Table III in gram calories per second per inch cube per deg. C.

Table III.

Material	Average k at 100 deg.	Average k at 1000 deg.
Woodland	0.0043	0.0086
Quartzite	0.0051	0.0086
Star silica	0.0056	0.0108

For magnesite brick it was found that between 445 deg. and 830 deg. C. the conductivity of the magnesite brick was practically constant, the value being 0.0343 gram calories per second per inch cube per deg. C. For this reason magnesite brick is not included in the above Table III.

It is estimated that the precision of the figures representing mean conductivities is within 5 per cent. The precision of the average figures representing the conductivities at definite temperatures is less, but it is difficult to estimate.

In the absence of Professor Dudley, his paper was presented by Dr. Richards. It was discussed at some length by Messrs. Hering, Schluederberg, Hitchcock, Addicks, Chapin, Northrup, Frary, and Richards. Dr. Hering pointed out that Dudley's method of measurement gives directly the heat conductivity of the solid material and eliminates the surface resistance to flow of heat. This additional resistance may become important in practice. Mr. Hitchcock replied that the thermal resistance of the solid material is really what is wanted by the practical man; he plotted curves to show that the additional surface resistance is relatively insignificant. Dr. Northrup emphasized the altruistic character of such heat-conductivity experiments with their immense technical difficulties and the enormous expense of time they require.

Reaction Between Graphite and Magnesia

A paper by Professor **O. L. Kowalke** and Mr. **D. S. Grenfell**, of the University of Wisconsin, gave an account of measurements of the temperature of reaction between Acheson graphite and magnesia.

Three different methods were used: In the first method, weighed samples of the two materials—magnesia and graphite—were heated in contact with each other for half an hour at various temperatures and the loss in weight determined.

The second method was based on the fact that the reaction is endothermic. When the substances attain the reaction temperature, heat will be absorbed from the surroundings and the temperature falls, which becomes manifest in the pyrometric curves.

The third method employed a vacuum furnace; the beginning of the reaction would be detected by an increase in pressure.

The second method gave the best results. The pyrometric curves indicate that the reaction commences slowly at about 1950 deg. C. and becomes very violent at temperatures above 2030 deg. C.

The paper which, in the absence of the author had been presented by Professor Frary, was discussed by

PHOTOGRAPH TAKEN AT ATLANTIC CITY MEETING OF AMERICAN ELECTROCHEMICAL SOCIETY

Messrs. Bennett, Northrup, Hinckley, Whitney, Richards, Mott, Hitchcock, Frary, Saunders and FitzGerald. The latter thought that such reaction temperatures are rather indefinite.

Analogies Between Electricity and Mechanics

In the evening of Thursday, Professor W. S. Franklin of Lehigh University, presented a most interesting experimental lecture on "some mechanical analogies in electricity." The principal object was to show some exact analogies between rather difficult yet fundamental conceptions in alternating-current engineering and well-known mechanical conceptions. Professor Franklin showed especially the analogy between induction in electromagnetism and inertia in mechanics and the analogy between a condenser in electromagnetism and and an elastic medium in mechanics.

Professor Franklin's experiments were striking and the audience was still more impressed by the decidedly original viewpoint of the lecturer, which may be indicated by his quotation, made in concluding the lecture, from his recent little textbook "Elementary Electricity and Magnetism" (Macmillan Co., 1914, page 56):

"Electricity or energy; which? When water is pumped through a pipe it is usually the amount-of-water-delivered-in-a-given-time that is important. The amount of power represented by the stream of water is of no great importance. It is the water itself that is useful, and the power expended in driving the pump is merely enough to carry the water where it is needed. But one might conceivably use a pump to drive water through a circuit of pipe for the sake of the heating effect of the moving water in the pipe or to drive a water motor placed anywhere in the circuit of pipe. In such a case one would be interested primarily in the amount of power represented by the stream of water because the desired effect (heating or motor driving) would depend upon the amount of power.

"So it is in the case of the electric current. It is not 'electricity' (whatever that is) that one uses, it is work or energy; and the important thing about an electric generator (a battery or dynamo) is the amount of power represented by the electric current delivered by the machine. This may be illustrated most pointedly as follows: A wheel drives another wheel by a belt. A person knowing nothing at all about machinery and especially a person having no available words to use in describing such an arrangement, might look at the continuous stream of leather given off the first wheel and decide to call this wheel a leather generator! Everyone knows, however, that a driving wheel does not generate leather; it gives off energy work and the work is transmitted to the driven wheel by the belt. It seems very ridiculous to speak of a belt-wheel as a generator of leather, and indeed it is equally absurd to speak of a battery or dynamo as a generator of electricity. One must be careful not to take electrical terms and phrases too literally.

"To speak of a dynamo as an electric generator is, however, not seriously objectionable, but to speak of 'electricity' as a motive power indicates a very serious misunderstanding. When it is proposed to drive a machine by a leather belt it is always understood that something must drive the belt, but when it is proposed to drive a machine by 'electricity' it is not always understood that something must drive the 'electricity'. Electricity as applied in the arts is merely a go-between like a leather belt, and no one ever thinks of leather as a motive power!"

Friday Morning Session.

The Friday morning session was opened by the presentation of two papers by Dr. W. D. Bancroft, of Cornell University, on colloidal chemistry. In Professor Bancroft's absence the first paper was presented by Dr. Whitney, the second by Professor Frary.

Coagulation of Albumin by Electrolytes

A paper by Professor **Wilder D. Bancroft**, of Cornell University, reaches the following conclusions:

So far as the data go the coagulation of albumin by salts can be accounted for more satisfactorily on the assumption that we are dealing primarily with

adsorption rather than on the assumption that we are dealing primarily with an amphoteric electrolyte.

Slightly acid or slightly alkaline solutions of albumin are least stable when the dispersed phase is electrically neutral.

Since the sign of the electrical charge depends on the preferential adsorption of cation or anion, the nature of both anions and cations is important.

When albumin is charged positively, the most strongly adsorbed anion will be most effective in causing precipitation and the most strongly adsorbed cation in preventing precipitation.

When albumin is charged negatively, the most strongly adsorbed cation will be most effective in causing precipitation and the most strongly adsorbed anion in preventing precipitation.

If one adds to negatively charged albumin a salt consisting of a readily adsorbed cation and a slightly adsorbed anion, we shall get precipitation at low concentration and no precipitation at higher concentration; but in this latter case the albumin will be charged positively.

While the reversibility of precipitation depends in part on the ease with which the precipitating agent can be washed out, it seems probable in the case of albumin that the physical properties of the precipitate are important as determining coalescence and agglomeration. There are no data on this point.

In the case of electrolyte-free albumin one must apparently assume that the stability of the solution is due to the peptonizing action of water in the absence of electrolytes.

The coagulation of albumin by electrolysis is a typical and general case, whereas the coagulation of gold sols and ferric oxide sols are special cases.

Neutralization of Adsorbed Ions

A paper by Professor **Wilder D. Bancroft,** of Cornell University, reaches the following conclusions:

The neutralization of an adsorbed ion is due to specific adsorption. The concentration of a given electrolyte necessary to neutralize the charge on a given colloid will therefore depend on the nature of the cation, the anion and the colloid.

It is inaccurate to say that the cation is negligible in the precipitation of a positive colloid and the anion in the precipitation of a negative colloid, though this statement is often approximately true.

Univalent ions are not all adsorbed alike; nor are bivalent ions or trivalent ions. The order to adsorption is specific with each colloid and is not determined exclusively—and perhaps not at all—by the migration velocity or solution pressure of the ion.

Since the adsorption is specific, Schulze's law is only an approximation. Certain univalent ions are adsorbed by certain colloids more than certain bivalent or trivalent ions. In many cases there is, however, a marked tendency to increased adsorption with increasing valence.

Mixtures of two sols will not precipitate each other unless adsorption takes place.

Since adsorption is specific, the order of precipitation of a negative sol by a number of positive sols will not necessarily be the same for any two negative sols.

It is not accurate to say that two sols having the same sign have no effect one upon the other. Adsorption may and often does take place.

Hydrous chromic oxide, which is peptonized by caustic potash may act as a protecting colloid for hydrous ferric oxide, which is not peptonized by caustic potash.

Since an adsorbed ion does not necessarily give the reactions of a free ion, electrometric measurements may and do lead to false conclusions when applied to colloidal solutions.

It is probable that sodium palmitate solutions are hydrolyzed to a very much greater extent than appears from electrometric measurements.

If two colloidal sols did not adsorb each other appreciably and if one adsorbed the cation of a given electrolyte very markedly, while the other adsorbed the anion of the same electrolyte very markedly, the addition of a small amount of the electrolyte to a mixture of the two colloids would produce a solution which would conduct electricity without their being any appreciable amount of substance in true solution.

In sodium palmitate solutions, it seems probable that the hydroxyl ions set free by hydrolysis are adsorbed practically completely by the colloidal soap.

Addition of a colloid to a solution will increase or decrease the conductivity if the adsorbed ion has a greater or smaller migration velocity than the ion adsorbed. In so far as both ions are adsorbed the conductivity will decrease.

When adsorption by a colloid causes hydrolysis the conductivity will depend also on the nature of the products of hydrolysis.

The two papers elicited a very interesting discussion on colloidal chemistry in general in which Messrs. Whitney, Cox, Lidbury, Franklin, Jacobs, Mott, Frary and Taylor participated. One one side Dr. Whitney emphasized the enormous present importance of the development of colloidal chemistry where new and important results are constantly obtained, especially in the explanation of biological phenomena, for instance, the action of the heart, and President Lidbury urged that while in the past biologists had almost monopolized the field of colloidal chemistry, electrochemists should now

TABLE I—THERMO EMF OF IRON-NICKEL ALLOYS. (AGAINST COPPER. 0 TO 100 DEG.)

Fe	Ni	Si	C	T. E. F. Millivolts
100.	.....	.....	.....	+ 0.86
83.	17.	.....	.....	— 0.64
80.	20.	.....	.....	— 0.55
70.	30.	.....	.....	— 0.52
66.5	33.5	0.16	0.25	— 0.48
18.8	81.2	0.014	0.19	— 2.45
7.	93.	.....	.....	— 1.90
4.6	94.6	0.64	0.11	— 1.40
3.2	96.3	0.35	0.12	— 2.00
.....	100.	.....	.....	— 2.38

TABLE II—THERMO EMF OF IRON-CHROMIUM ALLOYS. (AGAINST COPPER. 0 TO 100 DEG.)

Fe	Cr	T. E. F. Millivolts
90.	10.	1.20
82.	18.	1.04
80.	20.	0.43
76.5	23.5	0.32
70.5	29.48	0.31

TABLE III—THERMO EMF OF IRON-COBALT ALLOYS. (AGAINST COPPER. 0 TO 100 DEG.)

Fe	Co	T. E. F. Millivolts
90.	10.	— 0.64
80.	20.	— 3.70
70.	30.	— 3.50

TABLE IV—THERMO EMF OF IRON-NICKEL-CHROMIUM ALLOYS. (AGAINST COPPER. 0 TO 100 DEG.)

Fe	Ni	Cr	Mn	Si	C	T. E. F. Millivolts
79.	17.	4.	...	...	...	— 0.12
70.	20.	10.	...	...	...	— 0.46
35.	55.	10.	...	...	...	0.00
25.	60.	15.	...	...	...	0.07
25.	55.	20.	...	...	...	0.07
20.	55.	25.	...	...	...	— 0.08
17.5	75.5	7.	...	0.03	0.22	0.20
16.3	70.6	13.1	...	0.02	0.17	0.20
16.3	70.6	13.1	...	0.02	0.20	0.17
9.6	57.7	31.9	0.20	0.30	0.40	— 0.08
6.4	69.	22.7	0.30	0.25	0.20	0.24
5.	84.	11.	...	0.40	0.034	1.49
4.5	81.	13.6	0.30	0.30	0.17	1.00
4.	89.6	5.65	...	...	...	1.70
4.	80.4	15.6	...	0.58	0.23	0.76
3.8	89.7	5.6	0.25	0.40	0.18	1.51

make this field their own. On the other hand, Professor Frary, in presenting Dr. Bancroft's second paper, showed how in various instances the point of view of the "old chemistry" was able to explain matters quite as successfully as the colloidal chemist's viewpoint. The whole discussion not only contributed to a more general understanding of such conceptions as adsorption, as distinguished from absorption, but undoubtedly created a broader interest in colloidal chemistry.

Thermo-Couples

A paper by Mr. **T. S. Fuller,** of the Research Laboratory of the General Electric Company, Schenectady, N. Y., gave the results of the measurement of "the thermo emf of certain iron alloys." The methods employed were described and the results given in tables and diagrams. The results for iron-nickel, iron-chromium, iron-cobalt, iron-nickel-chromium and iron-nickel-manganese are given in Tables I, II, III, IV and V.

TABLE V—THERMO EMF OF IRON-NICKEL-MANGANESE ALLOYS. (AGAINST COPPER. 0 TO 100 DEG.)

Fe	Ni	Cr	Mn	Si	C	T. E. F. Millivolts
87.	10.	...	3.	...	...	— 1.09
86.	12.	...	2.	...	...	— 1.02
81.	17.	...	2.	...	...	— 1.50
80.	17.	...	3.	...	...	— 0.79
76.5	17.5	...	6.	...	...	— 0.73
76.	22.	...	2.	...	...	— 1.84
50.	44.	...	6.	...	...	— 0.59
33.6	58.3	0.31	6.6	1.	0.16	— 0.94
5.	82.8	0.11	12.	0.058	0.068	— 1.11
5.	88.5	0.11	6.2	0.061	0.065	— 1.60

The paper was discussed by Messrs. Fink, Mott, Gillett, Jacob, Whitney, Richards, Hinckley, Ruder, and Fuller. The hope was expressed that these measurements would be extended to higher temperatures.

LeClanche Cells

A paper by Professor **M. deKay Thompson** and **Ernest C. Crocker** of the Massachusetts Institute of Technology deals with the depolarization in LeClanche cells.

In the LeClanche cell the positive electrode consists of carbon in contact with manganese dioxide. The dioxide acts as the depolarizer, but does not depolarize completely, as is shown by the gradual decrease in the current and voltage on closed circuit. LeClanche recommended that the manganese dioxide should be mixed with carbon and that both should be coarse in size. LeClanche cells, in various forms, are extensively used at the present time, especially as dry cells. About fifty million a year are manufactured in the United States alone. Wet cells are also made in smaller quantities.

In view of the considerable difference in sizes of the depolarizer particles, used in different makes of LeClanche cells now in commercial use, the authors made a study of the comparative efficiency of depolarizing mixtures of carbon and manganese dioxide, when the sizes of the particles and the relative amounts of the substances present in the mixture were varied. The chief result of their investigation is that the carbon and pyrolusite particles should have the same size, and this should be such as to allow the particles to pass through openings 1/10 inch (0.25 cm.) square and not to pass through openings 1/120 inch (0.02 cm.) square.

The purity of the pyrolusite affects the depolarization materially. The mixture of carbon and pyrolusite should contain 55 to 60 per cent pyrolusite.

In addition, the authors investigated the cause of polarization in LeClanche cells. It is assumed to be due to the decomposition of the anmmonium radical and its subsequent splitting up, represented in the equation $2NH_4 = 2NH_3 + H_2$. The polarization may, therefore be due either to hydrogen or to ammonia. The investigation shows that the polarization by hydrogen is completely prevented by the manganese dioxide. The remaining depolarization in the LeClanche cell is due to ammonia. This may be largely overcome by the addition of zinc chloride to the solution.

Communicated discussions by Professor Burgess and Dr. Cheney were read and Messrs. Richards, Frary, Whitney, Hitchcock and Franklin participated orally in the discussion. It was pointed out that pyrolusite is a rather variable mineral. Further attention was called to the fact that university professors have to undertake such work, because the commercial companies which have all this information in their files would not publish it.

Copper Leaching

The concluding number on the program of the Friday morning session was a general discussion of leaching of low-grade copper ores with subsequent electrolytic precipitation. This had been the subject of an extended discussion on Jan. 6, 1915, at a joint meeting of the New York sections of the American Electrochemical Society and the American Institute of Mining Engineers. In view of the representative character of the engineers who took part in that discussion, it was of unusual value, being a condensed statement based on wide experience. At Atlantic City a review of the chief results of this discussion was given by Mr. Addicks. We will first give a rather full account of the original New York City discussions and follow this by an account of the additional discussion at Atlantic City.

Discussion in New York

Dr. L. D. Ricketts opened the discussion, expressing his deep interest in the subject and in the value of free discussion by men having special qualifications to consider different phases of the work. He outlined the problem existing at the New Cornelia property at Ajo., Arizona, where there is about 40,000,000 tons of ore containing 1½ per cent copper; 12,000,000 tons is oxidized, 24,000,000 tons sulphide, and about 4,000,000 tons is a mixture of the two classes. Other large tonnages of oxidized ore of low grades were mentioned showing the importance of their treatment.

In our issue for September, 1914, page 591, we presented an abstract of Mr. Stuart Croasdale's paper read at the Salt Lake meeting of the A. I. M. E., giving the results of his experiments on the New Cornelia ore. This ore has a matrix of granite with a large percentage of secondary quartz replacing felspar. There is little calcium present in soluble form, and the oxidized seems adapted to a leaching process.

"Preliminary laboratory tests showed that the ore crushed with the production of remarkably little slime and that the copper will dissolve in dilute sulphuric acid quite freely when the crushed ore contains fragments no larger than 6-mm. cubes. Tests also showed that a little cuprite is present, which is only partly soluble in sulphuric acid. There are also other soluble salts, notably salts of iron and aluminum. It was decided to investigate a leaching process for the oxidized ore, and since the ore made but little fines and could be leached with comparatively coarse crushing, we decided that we would try to leach in tanks by percolation. The amount of silver in the ore is small. Salt is apparently expensive, and it was decided that, other things being equal, the use of chlorine compounds as solvents was not desirable.

"Mr. Croasdale demonstrated that the ore crushed to an 8-mm. cube, or smaller, would yield over 80 per cent of its copper when treated with a dilute solution of sulphuric acid. He demonstrated that slime

presented no difficulty if the ore was distributed in the tanks uniformly, and that by finer crushing 85 per cent of the copper could be obtained in solution if treated for a sufficient length of time with an acid solution. He demonstrated not only that the ore was permeable uniformly, but that with comparatively small tanks the height was not a matter of great consequence, and he was easily able to use a column 12 ft. in height, and could probably use one much higher. Later on we found upward percolation preferable.

"Mr. Wedge showed us that with care in calcining the sulphide fines for reverberatory furnaces at the Calumet & Arizona smelter at Douglas, sulphuric acid of 55° to 60° B. could be manufactured with a low operating cost, and a construction cost of not to exceed $3,000 per ton of daily capacity. The point of manufacture is about 300 miles, more or less, according to the route, from the mine. Mr. Wedge also undertook a study of sulphating and chloridizing roasts. His requirement were that the ore be crushed to pass a 1½-mm. screen. He showed that if the sulphide ore could be mined in parallel with the oxidized ore, and in proportion to their respective tonnages, there would be sufficient sulphur for his purposes and that a very high extraction could be obtained. He also showed that sufficient advantage could not be had in using salt to offset its cost and the difficulties that might arise later. Mr. Wedge also showed that a small amount of heavy sulphides from the Bisbee mines crushed and mixed with the oxide ore would give a very high percentage of extraction after the mixture had been subjected to a sulphating roast. He also introduced the idea that a preliminary water leach would give a perfectly pure sulphate solution from which the copper could be recovered electrolytically and that the acid thus regenerated would be sufficient to complete the leach."

Reference was made to the experimental work of Mr. Laist, at Anaconda, where is was found that by calcining sulphide or mixed ores a high percentage of copper could be extracted by leaching. Temperature control was shown to be vastly important, by both Messrs. Wedge and Laist. Mr. Ricketts made reference also to the McKay process, using a sulphatizing roast to render copper soluble; also the slater and Midland processes, which depend on the use of complex chlorides and hypochlorous compounds to attack copper compounds not affected by sulphuric acid.

"At the beginning of our investigation we seriously considered what I called the 'brutal method' of leaching, namely, the manufacture of sulphuric acid, the solution of the copper from the ore with such acid, and the precipitation of the copper by metallic iron, with the resultant complete, or nearly complete, destruction of both acid and iron and the production of an impure cement copper that will have to go through the process of smelting and refining. The results of Mr. Croasdale's tests and Mr. Wedge's cost figures indicated that such a course was commercial, and we concluded that the 1½ per cent Ajo ore, with no overburden, mined by steam shovel and crushed coarse, would yield a profit on a 12c. copper market if a cheap grade of Alabama pig iron were used.

"But it occurred to me, as it had occurred to many engineers, that oxide of iron could be reduced to metallic iron without fusion, and if so we might bring Bisbee sulphides to the mine, calcine them for the manufacture of sulphuric acid and then metallize the available iron in the impure calcine, already containing values requiring recovery, and use this for a precipitant."

The experiment of metallizing was tried in a small Wedge furnace, but was a failure because in keeping the charge hot the CO_2 formed was sufficient to retard and reverse the action of CO in reduction. Experiments in revolving cylinders, using illuminating gas and fuel oil in a continuous process, also were a failure. Mr. Laist, however, had demonstrated that sponge iron could be made in a revolving drum by an intermittent process. Mr. Ricketts became convinced that the use of iron, with destruction of both iron and acid, was preposterous, and decided to investigate electrolytic processes of deposition, and later the precipitation of copper by sulphurous acid gas.

PRECIPITATION BY SULPHUROUS ACID GAS

"In the precipitation of copper by sulphurous acid gas, temperature and consequent pressure must be considered. If the copper is precipitated in metallic form this temperature and pressure are very high, but if a sub-chloride of copper would satisfy us, the temperature and pressure may be moderate. In both of these processes, the reactions we are familiar with in the formation of sulphurous acid by treating copper turnings with concentrated sulphuric acid are reversed by heat. For the production of metallic copper the action depends upon getting sulphurous acid dissolved in the sulphate solution in sufficient amount to precipitate the copper and then heating the mixture under proper control to about 150° C. The question of the use of an abnormally rich gas is involved. Under proper regulation pure copper is produced, which only needs melting for the market, and a large excess of sulphuric acid is formed. Mr. Van Arsdale has done valuable original work on this process, followed by the work of Weidlein and others in its commercial development. Laist has studied precipitating sub-chloride of copper. A soluble chloride is added to the sulphate solution of copper and the proper amount of sulphurous acid is added. Moderate heat under pressure—90° C. of heat—precipitated almost all the copper as sub-chloride. The subsequent process of obtaining the copper without volatilization and the recovery of the chlorine offered difficulties. It is with no disparagement of the process that we have abandoned it in our case. To me and my friends the electrolytic method seemed best adapted to our condition and the simplest and more certain of commercial application.

INVESTIGATION OF ELECTROLYTIC METHODS

"Of course, the first difficulty was the solution of other oxides than copper and the danger of some loss of acid thereby, and, what was more important, the susceptibility of some of these dissolved neutral salts to oxidation by nascent oxygen to the production of acid salts, which in turn will dissolve copper from the cathode. It seems that such salts are most valuable as depolarizers, but must be held under control."

Mr. F. L. Antisell and Messrs. Pope and Hahn were employed to make a series of tests and experiments covering the difficulties offered by iron and aluminum.

"Both Mr. Antisell and Messrs. Pope and Hahn began their experiments upon a laboratory scale at the Raritan Copper Works. Messrs. Pope and Hahn found the leaching could be so conducted that the rate of increase of iron and alumina was slow. They therefore decided to leach in a certain way and to treat a certain high iron and aluminum neutral solution with copper oxides by agitating, heating, and injecting air. This is a rejuvenation of the old Hoffman process applied to a new purpose. The iron and aluminum sulphates in such foul solution, together with arsenic and other impurities, are precipitated as insoluble oxides and the acid previously combined with these

salts is taken over by the copper oxide and forms sulphate of copper. The clarified solution, with these impurities removed, is then mixed with the balance of the solution, thus keeping an iron content of, say, less than ¾ per cent.

"Mr. Antisell began his experiments by using a patent anode. This anode was a narrow, rectangular wooden or lead frame with thin wooden sheets as diaphragms, forming a long and deep but very narrow box. It was packed with a clean coke in lumps crushed to pass a 1-in. ring, and contact was given by carbon rods imbedded in the coke. A solution of sulphate of iron and aluminum in great excess was made up and sulphuric acid added. This was used as a solvent for the copper. After the solution came from the ore it was at first passed to an absorption tower, where sulphurous acid gas was absorbed, and then it passed to the electrolytic tank.

Promising results were obtained in the laboratory, and later tests were made with full sized anodes at Douglas. Excellent results were obtained there also, but difficulty was had with the complete absorption of sulphurous acid. An extraction of 80 per cent was obtained, and 2 lb. copper was recovered per kilowatt-hour. Nearly the theoretical amount of sulphuric acid was produced from the SO_2 gas.

"Mr. Greenway discovered that if a certain copper solution containing salts of triad elements is treated in a simple way, the iron or aluminum triad salts may be removed. Dyad salts are not affected. He was led to the belief that such oxides thus precipitated were in large part insoluble in dilute acid and that therefore he had a very simple method of removing iron and aluminum from the solution. Against my prediction, laboratory tests seemed to show his contention was correct. Mr. Greenway erected a small plant of his own, and a Pope and Hahn plant was installed and the use of sulphurous acid was temporarily discontinued. As for the Greenway process, I am not yet at liberty to discuss it further. But I may say over 100 charges were run with this process. The iron content in the solution was kept down to less than 1 per cent, and we obtained an average of slightly over 1 lb. of copper per kilowatt-hour, but the extraction was low. We then extended the time of the leach and obtained a higher extraction, and finally we began to crush the ore, which at that time had been crushed only to ½-in. ring, finer, and found that if crushed to pass ¼-in. mesh percolation was not retarded and an extraction of over 80 per cent was practicable. The iron has reached as high as 1.2 per cent, but we are still getting a pound of copper per kilowatt-hour from the electrolytic tanks.

"These experiments have been so successful that we are proceeding with the erection of a 40-ton plant, where tanks will be used that will hold 60 tons, if necessary, and will be abundantly large to permit of a study of the comparatively even distribution of crushed ore, and we shall proceed with these most interesting experiments, using first, as we have in the smaller tanks, the Greenway process. In the meantime, the 1-ton plant will be liberated and we will immediately proceed with the continuance of a modified form of the Antisell system of leaching. He finds that with the construction of better absorption towers we can absorb the necessary amount of SO_2 gas, and he has demonstrated that with the use of SO_2 gas, using dyad iron as a depolarizer and triad iron as an oxidizer, he can manufacture sulphuric acid. We can, if successful, obtain 1½ lb., and possibly more, of copper per kilowatt-hour, and at the same time manufacture sufficient acid to replace wastage. The electrolytic copper in all cases has been fully up to the trade standards.

CONCLUSIONS

"My deductions from a study of the work of the able engineers engaged in these extensive operations are as follows:

1. Dilute sulphuric acid will give a very high extraction on oxidized ores of the Ajo type. Time is a more important element in extraction than strength of acid. A maximum size of 6-mm. cube is required. Such ore crushed to the maximum size permits percolation and the production of a clear solution because the slime content in the ore so crushed is very small.

2. Where such ore is mined at a cost of between 25c. and 50c. a ton, it is commercial on a 12c. market, even if leached with sulphuric acid and the copper precipitated with pig iron to the waste of the acid and iron and the production of an impure cement copper that requires further treatment. Metallized iron from calcines can be made and will prove a little cheaper than pig iron if it is marginal.

3. An electrolytic method for the recovery of pure copper from sulphate solutions is far preferable and will produce cheap copper. In all cases a low current density is required. Hard-lead anodes or composite anodes of hard lead and coke of uniform thickness will be used.

4. Such electrolytic method, with control of the amount of iron and aluminum in the electrolyte, and without the use of sulphurous acid gas, is practicable. An acid loss of about 1.5 lb. per pound of copper will be sustained. Chamber acid will be required.

5. I believe there is a decided probability that the cheapest and best method will be the electrolytic deposition from sulphate solutions without iron control, and the use of the requisite quantity of sulphurous acid. The sulphurous acid will be absorbed without the tank house and in quantity that will not cause annoyance. Iron and aluminum will act both as depolarizers and catalytes. This process promises a high yield of cathode copper per unit of power and the manufacture of sufficient sulphuric acid to replace the waste.

6. While these remarks apply to the Ajo oxidized ore and ores physically and chemically similar, they need not apply to ores of a different composition. Mixed oxide and sulphide ores, be the sulphide chalcocite or chalcopyrite and bornite; ores containing great quantities of clay, or presenting other difficulties, have to be considered separately, and there is beyond question a great field for other processes and for other methods, both for obtaining the copper in solution and obtaining the copper from the solution."

Mr. Utley Wedge called attention to the necessity for making provision for the treatment of the sulphide ore of the New Cornelia, of which there is twice the tonnage that exists of oxidized ore. In his opinion a combination treatment can be evolved that will take care of both types of ore.

"Let the sulphide ore and the ore which is found between the mass of carbonate and the mass of sulphide ore, which partakes of the character of both, be ground to 20 or 30 mesh and furnaced at a temperature not much above a red heat, and the material can at once be leached with as good percentages of recovery as have been secured in the case of the carbonate ore. The copper solutions secured can be electrolyzed, and sufficient sulphuric acid can be produced from the electrolysis for use in leaching all or a portion of the carbonate ore, which methods can be identical with the methods described in the paper.

"I am of the opinion that sulphatizing roasting of

the sulphide ore in the orebody of the New Cornelia Copper Co., coupled with the acid leaching of all or a portion of the carbonate orebody with sulphuric acid by the methods indicated in the paper, will give the lowest possible cost of operation and will give the highest possible recovery of values of any method known to the metallurgical art. This combination of methods would obviate the necessity of construction of a sulphuric acid plant; in the place of this plant there would be constructed a furnace plant for giving the required roast to the sulphide ore. At the start, with only carbonate ore accessible, enough of the carbonate ore could be roasted mixed with small percentages of iron pyrite from neighboring camps to sulphatize the carbonate of copper."

Mr. E. A. Cappelen Smith outlined again the work at Chuquicamata. This has already been published in detail in this journal, May, 1914, page 291. The leaching plant is practically finished, but delay has been occasioned in the completion of the power plant, which is being made in Germany.

Mr. George W. Van Arsdale spoke briefly on the work at Douglas, Arizona, the method used consisting in sulphatizing-roasting, leaching and electrolysis of sulphate solutions, using depolarization.

"The results of our roasting experiments were as follows: We roasted three principal classes of material, in which the average insoluble copper in the calcines was 0.11, 0.16, and 0.41. The water-soluble copper showed 70 per cent of the copper contents, 40 per cent, and 51 per cent, respectively, and the total extraction was 92.9, 88.0, and 70 per cent. One of the principal results of these experiments was to show us that for this class of roasting it was necessary to have more or less fine crushing as a preliminary.

"The results of our preliminary electrolytic experiments were fairly satisfactory. We obtained a total amount of copper precipitated of something over 2 tons at an average figure for power of about 1.6 lb. of copper per kilowatt-hour. We produced acid per kilowatt-hour equivalent to about 5.1 lb. The ampere efficiency was low. This, however, was due to several reasons not directly connected with the process. We had a large number of short-circuits and other troubles, but we felt quite sure at the end of these preliminary experiments that we should get about 2 lb. of copper per kilowatt-hour. We had, however, a certain number of uncertainties and some anomalous results, so we started some further experiments on details of solution and other matters.

"The further experiments resulted in the following general conclusions:

"First, that it was not necessary to have such a large amount of SO_2 in solution as we had previously thought, and that in addition, much better results could be obtained by using SO_2 together with iron, rather than either one alone. In other words, the function of the SO_2 was not only to act as a depolarizer, but also to act chemically in keeping the iron reduced. We also found there was a certain favorable effect from a high aluminum content. The temperature increase is favorable in the same way as in copper refining. With iron salts present there is a decreased ampere efficiency with increased temperature. This was counteracted by SO_2 and by increased current density.

"As a result of these further experiments, we laid down the conditions of high ferrous sulphate in solution, high alumina, a temperature of about 115° to 130° F., current density of about 15 amperes per square inch, and sufficient sulphur dioxide present to reduce the voltage, and maintained sufficiently to keep the iron in the ferrous condition, and under these conditions I expect it will be possible to get a yield of from 2 to 2.5 lb. of copper per kw-hour.

"As to 'foul solutions,' which has heretofore seemed to be the principal bugbear in electrolysis, as long as the iron can be kept in the ferrous state, which can be done by SO_2, it is fairly safe to say that, up to certain limits, better results will be obtained from so-called foul solutions than from pure copper sulphate solution.

"We are now about to start a 75-ton plant, in which we expect to apply the information which we have gained to the treatment of one class of ore, and the result of the work which will be done in that plant will no doubt be published later."

Dr. Raymond F. Bacon, director of the Mellon Institute of Industrial Research, presented the following on methods of precipitation. "Our work on electrolytic processes has been along two lines. First, to ascertain the optimum conditions for the electrolytic precipitation of copper from sulphate solutions obtained by the leaching of oxidized copper ores. In this phase of the work I may say that we finally obtained conditions under which we ran a solution over the ore through the precipitating tanks and then over the ore again, 20 cycles being completed, without any purification of the solution. There was precipitated on the average in these 20 cycles 1.86 lb. of copper per kilowatt-hour and the current efficiency on the twentieth cycle was fully as good as that on the first cycle. Our second line of work on electrolytic processes has been an attempt to find efficient and cheap depolarizers, so as to increase the amount of copper precipitated by a definite amount of electrical energy. We have found one very cheap substance which for short runs gave us 4 lb. copper per kilowatt-hour.

"In regard to the sulphur dioxide process, we have been actuated by this thought—it is necessary in most ores to have quite an excess of acid to take care of mechanical losses and to take care of alkaline substances in the ore. One way of doing this is along the line which has been spoken of, by using the sulphur dioxide in an electrolytic cell. We, also, have used sulphur dioxide in an electrolytic cell, but all of our work has tended to show that the efficiency of sulphur dioxide as an anode depolarizer in a sulphate solution is rather low. Because of this low efficiency, our calculations showed us that it is cheaper to precipitate directly with the sulphur dioxide under pressure than to use the sulphur dioxide as an aid to electrical precipitation; that is, the heat required for direct precipitation with sulphur dioxide will be cheaper in most localities than the electrical energy required either for straight electrical precipitation or for the combination in which sulphur dioxide assists the current. We all appreciate the advantage which any electrolytic process has of giving directly cathodes of electrolytic copper.

DISADVANTAGES OF ELECTROLYTIC PRECIPITATION

"On the other hand, it has seemed to us that for most localities and most conditions the disadvantages of electrolytic processes, as at present developed, outweigh this advantage. Some of the disadvantages of electrolytic processes are these: The fouling of solutions immediately and seriously cuts down the current efficiency. Changes in the character of the ore, particularly as regards soluble impurities, are always to be expected in large orebodies. The electrolytic process is very sensitive to changes thus brought about in the electrolyte. The installation and upkeep costs of the electrolytic precipitation process are very high and to obtain efficiency requires constant

supervision by high-priced men. One rather fundamental objection to electrolytic processes has not been discussed here to-night. In electrolytic processes, at least of the type which have been spoken of to-night, the copper content of the electrolyte can be reduced in the precipitation cells no lower than 1.5 per cent copper. That means that it is not easy to so conduct a cycle of leaching, precipitation, etc., that all of the water-soluble copper shall be removed from the ore and the volume of the solution in the cycle shall be kept constant.

"It is obvious that in any process in which there is practically complete precipitation of the copper, as in Weidlein's sulphur dioxide process, this washing difficulty does not arise. In place of losing soluble copper in the ore, one there loses a corresponding amount of sulphuric acid; and in Weidlein's process sufficient sulphuric acid is constantly being formed, so that this loss can be taken care of. As to the element of danger in processes in which a solution is heated under pressure, I would call your attention to the fact that there are thousands of boilers operating continuously in the United States under pressures considerably in excess of those used in the Weidlein process. We built in Nevada a 40-ton plant and we have had certain mechanical difficulties, as we expected to have. These difficulties we are meeting by the installation of a continuous process of precipitation. The advantages of continuous precipitation will be evident to all mill men. Our expectation that the cost of heat in this process of precipitating pure copper is less than the cost of electricity for electrical precipitation has been borne out. Of course, I recognize that there are localities where electrical power is so cheap that an electrolytic precipitation process should be the one to be considered, but I believe that for most localities in the western United States some of these other processes are more favorable as regards cost. In the Weidlein process, a very large excess of acid is constantly regenerated and all who have had experience in the leaching of ores know how desirable this is. In that connection I will say that we have developed a system of handling sulphur dioxide and a method of concentrating it from dilute flue gases. We believe we have made noteworthy progress in that direction, but I am not prepared at this time to go any further into that. In a short time we will be able to say a little more on the subject."

Mr. Frederick J. Pope described the experiments of A. W. Hahn and himself in controlling the effect of iron salts in solution. As between allowing them to remain in the electrolyte and there controlling their action, or removing them altogether, they decided on some process of removal.

"In considering how to remove iron from the electrolyte, we were reminded of the work which had been done by Hoffman at Argentine, where he precipitated iron from bluestone solution. Hoffman accomplished this by heating the solution in a suitable tank, agitating with air, and adding copper in an oxidized form. I think he used a roasted lead-copper matte. This work of Hoffman's gave us our idea for the removal of iron from the solution.

"For the copper oxide necessary in this work we have used high-grade copper carbonate ore, oxide formed by the roasting of cement copper, roasted high-grade sulphide ore, also roasted copper sulphide concentrates. In order to obtain a satisfactory reaction between the copper oxide and the iron, etc., in the solution, it is imperative to have the oxide material very finely divided. The roasted concentrates we used were ground in a small Abbé mill.

"From the Ajo carbonate ore we removed a little more than 2 lb. of iron per ton of ore treated. In order to keep the iron in the solution below the percentage deleterious to electrical efficiency, it was necessary to treat approximately one-quarter of the solution. We found that by manipulating the solution going on and off the ore in a certain way we could concentrate a large proportion of the iron in a certain part of the solution.

"In purifying, the solution was first heated to 195° to 200° F. When this temperature was attained agitation with air was begun and the finely ground oxide material was gradually added. Maintenance of a temperature of about 195° F. and agitation with air was continued for 3.5 hr. During the first hour all the ferric iron was precipitated. The removal of the ferrous iron was slower and we found that it was not advisable to endeavor to precipitate it all. In 3.5 hr. we easily precipitated 90 per cent of the total iron and at the same time removed 65 to 75 per cent of the alumina, 50 per cent of the manganese, and all of the arsenic, antimony, and bismuth which might be present.

"After the above operation the pulp was passed through a Schreiber wooden filter press. The solution came out beautifully clear and was sent to the high-acid electrolytic circulation system. We anticipated that with the precipitate produced we might have trouble with the filter cake; that it would be slimy and difficult to handle. We did not find it so. The cakes were 2 in. thick, firm, washed well, and the amount of copper in the form of unused oxide they contained was well within commercial limits.

"The only loss of acid is that entrained in the tailing, but this is easily counterbalanced by a proper control of roasting operations. Lead anodes were used, containing 4 per cent antimony, and the cost was estimated to be 0.2c. per ton of ore treated, with lead at 8c. per pound."

Mr. J. Parke Channing.—"The problem presented in the Miami district is a little different from that in the districts referred to in the discussion of this evening, inasmuch as the ore to be treated there is one which is a mixed chalcocite and carbonate. The gangue is particularly free from any impurities that go into solution, but the fact that both chalcocite and carbonate are present makes it a rather difficult problem. The particular ore deposit upon which we worked was that of the New Keystone, but the same class of ore existed in the Miami, and also on the Inspiration. The problem therefore presented to us was either a straight leaching one, which would have to be proceeded with by complete dead roasting, or else it would be a mixed process, water concentration followed by leaching, or possibly leaching followed by water concentration; and then finally, if flotation came in, we might have to make three bites of the cherry—that is, use water concentration, flotation, and leaching. You can readily see there would be a great many combinations and whether it would be desirable to leach first, then water concentrate, and then float, or whether it might be desirable to make the sequence different, we do not know. This Keystone ore averages about 2¼ per cent copper, of which anywhere from 30 to 40 per cent is oxidized. After making a number of concentration tests we decided upon attempting a dead roast; in other words, converting all to the copper into a soluble form and leaching it."

Mr. R. C. Canby—"The only thing I can think of which has not been mentioned is the circulation of the electrolyte. In our electrolytic work I designed the cells so that the solution, instead of flowing

lengthwise against the flat surfaces of the anodes and cathodes, flowed crosswise of the cell. In that way, in the use of sulphurous acid gas, I had hoped, by having a rapid circulation, to use a much smaller quantity of both copper and the depolarizing element in the electrolyte, with a correspondingly stronger current, and also to be able to precipitate the copper without heating the electrolyte. I was able to use a current density as high as 10 or 12 amperes per square foot with the temperature of the electrolyte about 18° to 20° C., and get a very satisfactory coherent deposit. I think that was the only novelty in the electrolytic work.

"The problem in roasting was to use our 14° Baumé fuel oil, to be burned at a temperature of 2000°, and yet keep our ore bed at not to exceed 800° to 1000° C. I accomplished this by using a furnace similar to that used for the Huntington and Heberlein process at El Paso, and at three other American smelting plants, the hearth revolving past the flame, so that I was able to roast the ore without at any time bringing the temperature of the roasting above the desired 1000° C., whereas the fuel was being burned at about 2000°, or a little over. The furnace was entirely of reinforced concrete construction and stood well."

Mr. Richard Lamb described his work in connection with a leaching and electrolytic copper plant at High Hill, Va., for the Virginia Copper Co., treating bornite and chalcocite ores. The ore contained 3 per cent copper, 1½ per cent sulphur, 89 per cent silica, 0.75 per cent lime, 1.5 per cent iron, 3 per cent magnesia and 0.35 per cent alumina. The ore was roasted in an Edwards furnace at a temperature of about 900° F. in order to convert iron to the form of sesquioxide, and leave the copper as oxide and sulphate. The roasted ore was treated in a leaching barrel with sulphurous acid of 10° Baumé for about 3 hr. The copper solution thus formed was filtered and electrolyzed, the sulphurous acid being changed to sulphuric. The voltage in each tank was 1.8, and a current density of 3 amperes per sq. ft. was used. The electrolyte was permitted to run from ¼ to ½ per cent copper when used for further leaching. The output was 30.6 lb. copper per hp.-day of 24 hours. With steam power costing $48 per hp.-year, the cost for electrolytic treatment was about ½c. per pound of copper produced. Total cost of producing copper was estimated at about 6.9c. per pound.

Discussion at Atlantic City

Mr. Lawrence Addicks, after having summed up the discussion which had been held in New York City, added some remarks of his own. Three essentially different problems should be distinguished. First, for sulphide ores roasting and leaching is now not very promising, on account of the tremendous quite recent developments in flotation. Second, for oxide ores, where conditions are favorable, leaching has come to stay. Third, mixed sulphides and oxides represent an entirely open problem and it is impossible to say which process will fit. The presence of silver and gold complicates the problem. As to precipitation, there is now an increasing tendency towards electrolysis. Scrap iron as precipitant is practically impossible, because there is not enough scrap iron available. Mr. Van Arsdale and the speaker found that carbon anodes can be used (which have heretofore been thought to be unsuitable in sulphate solutions); they used Acheson graphite electrodes. Compared with electrolytic copper refining, the bearing of all important factors is reversed in copper leaching.

While iron and aluminium had heretofore been considered the most detrimental impurities, they had now learned how to turn their presence to advantage and use the iron for depolarizer and let the aluminium sulphate grow and form a natural diaphragm which prevents the action of ferric sulphate on the copper cathodes. With a pressure of 0.7 to 0.8 volt they get 2 or 3 lb. per kw-hr.

Mr. G. W. Van Arsdale emphasized the two most important results of his leaching experiments: first, that graphite anodes can be used in sulphate solutions, and second, that it is possible to get along very well with foul solutions. Mr. Van Arsdale also discussed some interesting chemical reactions which they ran across in their experiments.

Mr. John V. N. Dorr showed in an interesting way how his well known machines, originally invented and designed for cyanide practice, are now being successfully used to solve certain mechanical problems in the three operations of copper leaching: dissolution; separation of dissolved copper from ore pulp, and precipitation.

Professors Frary and Richards also participated briefly in the discussion.

Friday Afternoon Session

After the discussion on copper leaching had been concluded Professor Frary presented his paper on the electrolytic production of magnesium.

Electrolytic Preparation of Magnesium

A paper by Professor **Francis C. Frary** and **Harry C. Berman,** of the University of Minnesota, gives an account of an experimental investigation undertaken to find the cause and cure of the difficulties met with in the electrolysis of molten magnesium potassium chloride. Early in their work the authors noticed that after electrolyzing magnesium potassium chloride for an hour in a large graphite crucible the electrolyte on cooling contained numerous dark spots. It was found that this was the suboxide of magnesium and the cause of its formation was further investigated with the following results.

Magnesium sub-oxide is formed during the electrolysis of magesium potassium chloride if magnesium oxide is present. A high temperature facilitates its formation. It is dark colored, heavier than either metallic magnesium or the double salt, decomposes water vigorously, is oxidized (if finely ground) in the air, and is apparently re-oxidized at the anode in the bath.

Magnesium sub-oxide cannot be formed by the reaction of magnesium (metal) on the oxide in the presence of the molten double salt at a bright red heat, and is apparently only formed under such conditions as exist in the electrolytic reduction of MgO.

Magnesium sub-oxide does not react upon a solution of anhydrous nickel chloride in absolute alcohol, while metallic magnesium does.

There is no evidence of the formation of a "metal fog" during the electrolysis, even at a bright red heat, and the dark appearance of the electrolyte under these conditions is due to the presence of the sub-oxide.

Magnesium oxide dissolved or suspended in molten magnesium potassium chloride does not react with dry hydrogen chloride, differing in this respect from lime. As the magnesium oxide cannot be removed from the electrolyte, its formation must be prevented during both the preparation of the electrolyte and the actual electrolysis.

Professor Frary's paper was discussed by Messrs. Lidbury, Richards, Taylor, Vorce and Bennett. Mr. Lidbury suggested that the black mass might have been something like a potassium-magnesium alloy and

refused to accept a new suboxide until it has been isolated and analyzed. Professor Frary summed up his reasons which led him to conclude that the lead mass cannot be anything else but magnesium suboxide.

Calorizing Metals

A paper by Mr. **W. E. Ruder,** of the Research Laboratory of the General Electric Company, Schenectady, N. Y., discussed the application of the "calorizing" process to various metals. The calorizing process consists in producing a rich aluminium alloy upon the surface of the metal to be protected and has already been the subject of a descriptive article in our vol. XII, page 730 (November, 1914).

The pieces which are to be calorized are packed in a mixture containing powdered aluminium. This mixture is made up of alumina and powdered aluminium with the addition of about 1 per cent of ammonium chloride. The aluminium varies from 5 per cent to 50 per cent by weight, depending upon the service to which the piece is to be put. For copper and brass parts the mixture is kept low in aluminium and the temperature of firing held at about 700° C.-800° C. For steel and iron, richer mixtures are used and the temperature of firing is increased to 900-950° C. These mixtures are used repeatedly with the addition of sufficient aluminium and ammonium chloride to make up for the loss at each firing.

Perhaps the most important application of this process is the treatment of iron to withstand high temperatures. While the pieces are kept at a high temperature, as in service, the originally narrow band of aluminium alloy on the surface widens as the aluminium diffuses into the iron.

This diffusion gradually lowers the amount of aluminium in the outside coating, especially if the piece be of heavy section. There is, however, a coating of Al_2O_3 all over the outside which still protects the pieces from oxidation, but if this is broken it cannot renew itself and deterioration sets in. This usually starts in spots.

This spotting, however, occurs only at temperatures above 1050 to 1100 deg. C. and may be prevented by using a small section so that the alloy when completely diffused still remains high in aluminium.

Calorized cast iron parts do not stand up quite as well at high temperatures as calorized wrought iron or steel parts, because of the large amount of gases they contain and also because of their tendency to swell. At 800-900° C., however, it stands up very well. Wires and thin ribbons can only be given a light coating if they are to be kept pliable, because the surface alloy is very brittle and unless very thin will check off.

This process is finding considerable application in furnace parts, pyrometer tubes, annealing boxes, combustion tubes, etc. The original dimensions are somewhat increased by calorizing, especially on the edges. On flat surfaces, however, there is only a very slight increase (0.002-0.004 inch = 0.05 to 0.1 mm.).

Copper parts are equally well protected by calorizing. The result in this case is to produce a coating of aluminium bronze very rich in aluminium. This coating protects the copper from oxidation right up to its melting point.

Nickel may also be calorized. Calorized nickel is particularly good to use in wire form because the coating, unlike that on iron, is not brittle. Thin ribbons for resistance furnaces, etc., when calorized remain quite pliable. Iron ribbon, on the other hand, becomes very brittle and must be shaped before calorizing or else shaped hot afterwards. Calorized nickel gauze is found to be very durable for combustion screens, etc., as it does not burn and remains pliable in heat.

In conclusion Mr. Ruder stated that calorizing protects metals from oxidation indefinitely at temperatures below 1000° C. Above this temperature it still increases the life of metal parts several fold. It is to be noted, however, that it forms no protection against ordinary atmospheric corrosion, except in the case of copper. The aluminium bronze formed in this case is also protective against corrosion.

The paper was discussed by Messrs. Addicks, Hinckley, FitzGerald, Mott, Richards and Vorce.

Fixation of Atmospheric Nitrogen

The conclusion of the Friday session formed a symposium on the fixation of atmospheric nitrogen. Two papers by Mr. Summers and Mr. Washburn respectively, were first presented which had already been read at a joint meeting of the New York section of the American Electrochemical Society and of the American Institute of Electrical Engineers.

The paper by Mr. **Leland L. Summers** giving a general review of the whole situation of fixation of atmospheric nitrogen, was abstracted at length in our April issue, page 241. At Atlantic City Mr. Summers himself gave an abstract of his paper.

The paper by Mr. **F. S. Washburn** on the cyanamide process is published in full in the present issue, page 309. At Atlantic City the paper was presented in abstract by Dr. Fink in the author's absence.

A "polemical note" on commercial nitrogen fixation, by Mr. **S. Peacock,** was then read. "The fertilizer industry of the United States uses annually somewhat more than 100,000 tons of combined nitrogen, computed as ammonia, and the annual increase averages about 8 per cent. The combined nitrogen recovered in the United States from the distillation of coal for various purposes may be stated as approximately 70,000 tons per year, with an annual increase of about 15 per cent; and this increase must be assumed to be practical for several years to come.

"As encouragement to commercial nitrogen fixation, it may be stated that many organic nitrogenous substances heretofore used in fertilizers are finding other and more remunerative uses; and with each year a stronger demand is made on sources of supply which must favorably affect nitrogen fixation. A serious limiting factor is the cost. To illustrate: to grow one bushel of wheat requires nearly four pounds of nitrogen, which at present prices on the farm somewhat exceed 60 cents in cost. It is evident that the cost is practically prohibitive.

"Agricultural nitrogen hunger has been a practical fact for generations, not because ample nitrogen could not be obtained, but because it cost too much. Practically, farmers resort to a form of nitrogen fixation by growing leguminous crops in rotation and otherwise, but unfortunately legume nitrogen is scarcely less costly than the commercial product. Commercially, the promblem is clear and explicit; either the price of farm products must be materially increased, or the cost of combined nitrogen must be lessened. The former may or may not indicate a confession of incompetency on the part of industrial chemists; it is the problem we have to consider.

"As a commercial undertaking, nitrogen fixation must remain substantially dormant so long as the ammonia produced as a by-product of coal distillation remains of such relative amount that it is capable of controlling the rewards of capital invested in nitrogen fixation. It may be accepted as a fact that no nitrogen fixation method has as yet been publicly proposed which can produce combined nitrogen as cheaply as coke by-product ammonia. However, many very prom-

ising processes have been suggested, and it is to be hoped that some one or more will prove successful. The paramount objective must be a producing cost at the factory not in excess of 4 cents per pound of ammonia; such process will lessen the cost of bread and greatly expand the consumption of fertilizer nitrogen.

"It is doubtful if any process simply effecting nitrogen fixation will attain the necessary efficiency; it is probably essential to work out a combination process which not only fixes nitrogen, but also accomplishes one or more additional useful reactions. An illustration of such process is the complementary formation of calcium carbonitride and phosphorus nitride, using a mixture of phosphate rock and carbon, with but one heat effect.

"With the low cost ammonia, oxidation processes will follow, solving the problem of cheap nitric nitrogen and such compounds as ammonium nitrate. The weak point of American industries generally is the enormous proportion of costs permitted to selling and distribution. Therefore, the concentration of associated values in final end products is an important factor. Thus, ammonium nitrate or ammonium phosphate are more economical than ammonium sulphate, calcium phosphate or sodium nitrate, as the latter carry constituents useless or worse than useless for industrial purposes.

"As the fertilizer industry must be regarded as the chief support of nitrogen fixation, the end products must be suitable for fertilizer needs. This implies a product constant in composition, soluble in water, not deliquescent, and one whose component parts do not readily assume undesirable forms, such as a gaseous or insoluble form. It is essential also that, when mixed with other fertilizer materials, such, for instance, as potassium salts, no reactions may occur tending to make the mixture hard and lumpy, or in any way lessen its dry granular state; otherwise the material cannot be used in distributing machines, and thereby becomes practically worthless.

"It may be assumed as a governing principle that a commercially successful nitrogen fixation process must give as an end product potassium nitrate, or ammonium nitrate, or primary ammonium phosphate; and, that the factory cost must not materially exceed 5 cents per pound of combined nitrogen figured as ammonia. It is true that the present price is several times that; but, having in mind the competitive power of by-product ammonia and the vast prospective increase in the production of same, capital is not justified in supporting a nitrogen project under other conditions.

"The host of synthetic ammonia processes, of which that of Dr. Haber is the best known example, can never become commercially important, though they may have a moderate local application.

"From the point of view of a somewhat intimate acquaintance with all the nitrogen fixation processes publicly known at this time, there is nothing in the above conclusions which should in the least discourage American technologists."

A very interesting and lively general discussion followed:

Mr. Summers would not agree with Mr. Washburn's claim that the cyanamid process was *the* solution of the atmospheric nitrogen fixation problem; on the contrary, he thought the tendency of nitrogen men in this country was toward direct combustion processes. He certainly did not think that the cyanamid process was the last word.

Dr. Bennett had sent communicated discussions both of Mr. Summers' and Mr. Washburn's paper. He thought no process was at present commercial and that byproduct coke-oven ammonia would fix the cost of ammonia and determine the success or lack of success of fixation process. While the cyanamid process was the cheapest fixation process, yet ammonia from cyanamid could not compete with byproduct coke-oven ammonia.

Mr. Mott gave and discussed a mathematical equation for the efficiency of arc processes for nitrogen fixation.

Dr. Fink thought all processes should be encouraged. Dr. Richards said that the Cyanamid Company expected rapid developments in the whole field, with many changes from present practice in the near future.

Mr. J. E. Johnson, Jr., gave figures on byproduct coke-oven ammonia and suggested that in arc fixation processes an atmosphere enriched in oxygen should be used.

Mr. Summers agreed this would be theoretically better, but the dissociation which, on cooling, followed the formation of nitrogen oxides made the success illusory. It is not possible now to utilize fully the temperature of the arc, because the gas products are not quickly enough removed. There is phosphate rock in enormous quantities in this country. But the commercial trouble in this country is the expense of distribution methods; the distances are too great, or what amounts to the same thing, the freight rates are too high. Phosphate rock is sent to Europe and brought back in form of fertilizer. Of course, improvements will take place. Mr. Summers, in concluding, remarked that the Birkeland-Eyde process was the only process which had made nitric acid in Europe on a really large commercial scale and that the success of the Ostwald process, in conjunction with cyanamid, on a large scale, was still questionable.

Dr. Backeland spoke of the development of the fertilizer industry as a problem of opportunity. Belgium up to now has been using more nitrogen fertilizers than Germany and has produced yields greater than anywhere in Europe. But Belgium was compelled to do so; it was a process of gradual logical development. The rents for land in Belgium were very high (compared with this country), as the laws were made by the land owners. On the other hand the wages for farm workers (families with women and children) were low. Their salvation was the use of fertilizers and they used plenty of it to pay the landlord. As a result of the co-operation of Belgian farmers, fertilizers cannot be obtained anywhere in the world at as low a price as in Belgium. And this is the reason of Belgium's agricultural success; but the whole development took time. In time conditions in this country, favoring a greater use of fertilizers, will become more like those in Europe.

Professor Franklin referred to the spontaneous combination of oxygen with iron in presence of water, and thought that a nitride process based on the spontaneous combination of nitrogen with some metal in presence of liquid ammonia might be promising.

Dr. Whitney did not agree with Mr. Peacock's remarks on the Haber process.

The further discussion dealt largely with the question as to what will determine the price of ammonia. Besides byproduct coke-oven ammonia other sources of ammonia were discussed. The production of ammonia from Mond gas producers which, as Dr. Richards stated, is in successful operation in England, is not in use at all in this country. Dr. Baekeland called attention to peat as a source of ammonia.

Saturday Morning Session

On Saturday morning an early train was taken for Philadelphia, where the concluding sessions of the con-

vention were held at the University of Pennsylvania.

The morning session was held jointly with the Illuminating Engineering Society.

The first speaker, Dr. H. E. Ives, was introduced by the chairman, Mr. Addicks, as the personal representative of the fire-fly.

The Illuminating Engineer and Ideal Light

Dr. **Herbert E. Ives,** of the United Gas Improvement Co., Philadelphia, Pa., emphasized four important points in modern artificial illuminating practice:

(1) Lack of thorough understanding between the engineer who produces the light and the engineer who exploits this light.

(2) In spite of great improvements made in artificial illumination the intrinsic brilliancy of modern lamps is by far too intense for our eyes.

(3) The color of modern illuminants is very often not satisfactory.

(4) In the best modern illuminants the light obtained per unit power is strikingly low.

The distinctive function of the illuminating engineer is the utilization of light sources in the most efficient manner. Dr. Ives suggested that the illuminating engineer rewrite his specifications. He must tell the light producing engineer exactly what is required as a final product. Anyone can admire the dazzling intensity of the arc lamp, but it took a real student of the essentials of light production like Langley to realize that the common fire-fly is a much more wonderful light source.

Commenting upon the intrinsic brilliancy of modern light sources Dr. Ives pointed out that the tungsten vacuum filament is 300 times as bright as the brightest object by day, namely, a white surface in the sun. The nitrogen-filled tungsten lamp is 1000 times as bright and it becomes necessary to employ reflecting and diffusing media. What we require is a surface source of an intrinsic brilliancy of not over 1/1000 candle power per square centimeter. A true luminous paint which could be easily excited at will would meet this idea. A low intrinsic brilliancy is in great demand. What is really wanted is not a brilliant point, but a surface of low intrinsic brilliancy, like the surface of a window square.

The efficiencies of modern illuminants are surprisingly low. If we figure from coal 1 per cent is the best figure obtainable today. Light is actually only a small byproduct. The total luminous efficiency of a 4-watt carbon lamp is 0.42 per cent, that of the yellow flame arc 7 per cent. These figures are based on 50 cp per watt as the mechanical equivalent of light.

Flaming Arc Carbons

The paper on this subject by Dr. **William C. Moore,** which was then called up for discussion, has already been printed in full in our January issue (vol. 13, p. 52, 1915), since it had been originally presented before the New York Section of the Society.

The paper, which, in the absence of the author, had been read by Mr. Mott, was discussed at considerable length by Messrs. Barrows, Franklin, Hering, Darrah, Miller, Fink, Moon, and Richards. Dr. Fink suggested the possibilities of using flame-arc carbons in electric furnace work and Mr. Mott agreed that the flame-arc characteristics distinctly indicates such possibilities, as the voltage-current curve of the flaming arc starts at lower voltages and rises less steeply than the curve of the ordinary arc.

Lighting of Electrolytic Tank Rooms

A paper by Mr. **R. E. Harrington,** of the Edison Lamp Works, General Electric Co., Schenectady, N. Y., discussed lighting of electrolytic tank rooms by means of tungsten lamps. Correct lighting increases safety and production, two factors of vital importance. This correct lighting may be secured by the proper selection of lamps and reflectors, the porcelain enamel reflector being given the preference. Of the various methods of lighting commonly employed the system of general illumination is most universally adaptable, although localized general lighting should be used where tanks are covered by hoods. Considering the question from a cost standpoint, experience has shown that in many cases the cost of proper lighting with the modern lamps is often less than improper lighting with the older types of lamps. In addition the advantages previously mentioned are obtained.

The paper was discussed by Messrs. Lidbury, Addicks, Stephens, Barrows, Franklin, Mott, Harrington, and Hogaboom. The question of the illumination of plating shops elicited quite an extended discussion of the best methods for producing artificial daylight for the correct matching of colors.

Saturday Afternoon Session

A complimentary luncheon at Houston Hall, tendered by the University of Pennsylvania to the Society and its friends, was greatly enjoyed. The afternoon session, held like the morning session at the Harrison Chemical Laboratory, was held jointly with the American Electroplaters' Society.

Electroanalysis

The session was introduced by an immensely interesting informal address of Dr. **Edgar F. Smith,** provost of the University of Pennsylvania. Dr. Smith said that it was for the fourth time that the American Electrochemical Society held a meeting at his laboratory and that there were good reasons why the society should feel at home in the congenial atmosphere of the University of Pennsylvania, where Robert Hare had worked on calcium to improve Davy's work and where Wolcott Gibbs had been a pupil of Robert Hare and had received the inspiration which led him to suggest the use of the mercury cathode in electroanalysis.

Dr. Smith then reviewed the very extended work of many years, carried out by him and his co-workers on electroanalysis. This sketch was as interesting in its chemical details as it was as a human document. He started his work on electroanalysis in 1878, but it took a long time to get converts. But by and by he and his case won out.

The latest achievement, described at the conclusion of the lecture, is a new method worked out by Dr. Smith and his assistant, Dr. Lukens, for the quantitative separation of cobalt and nickel. It is based on the observation that with a moderate current density nickel will not be precipitated from nickel ammonium fluoride, while the cobalt is precipitated. With a higher current density the nickel is precipitated as metal on the cathode and the cobalt as dioxide on the anode.

The lecture was illustrated by experiments, among which Dr. Lukens exhibited a simple method for agitating the electrolyte.

Cleaning and Plating in the Same Solution

A paper by Dr. **Oliver P. Watts,** of the University of Wisconsin, discussed the possibility of using the same solution for both preliminary cleaning and for plating proper. The author's experiments related especially to copper plating in connection with Lovering's solution, but some experiments were also made on brass plating and nickel plating.

The paper which, in the absence of the author, had been read by Professor Frary, was discussed by Messrs. Schluederberg, Addicks, Bennett, Hogaboom, Proctor, Benoliel and Frary.

Electrolytic Lead Deposits

A paper by Professor **Frank C. Mathers** and **Asa McKinney**, of Indiana University, points out that the electrolysis of solutions of lead nitrate ordinarily produces a mass of loose crystals upon the cathode. The authors have, however, succceeded in obtaining as smooth coherent lead deposits from lead nitrtate solutions as from any other lead bath.

The best composition of the bath is: 10 per cent lead nitrate, 2.5 to 5 per cent acetic acid and 1 per cent of the residue from the commercial extraction of Curacao aloes in the manufacture of aloin. Crude aloes may be used in the place of the aloes residue, but the deposits are not as good. The aloes or the residue should be dissolved by warming in the acetic acid before adding the lead nitrate solution. The bath should not be filtered before using. A current density of 0.4 amp. per sq. dec. (3.7 amp. per sq. ft.) may be used.

Free acetic acid is necessary in the bath to avoid the formation of basic salts. Free nitric acid in place of the free acetic acid greatly hastens the deterioration of the baths, and the greater the concentration of the acid the quicker the deterioration of the baths.

A number of addition agents were tried, but none approached the residue from Curacao aloes in efficacy. The aqueous extract of poplar wood, which gave excellent deposits in acetate baths, was not satisfactory in these nitrate solutions.

The baths have a life of only six or seven weeks, after which the deposits become spongy and non-arherent; consequently it seem unlikely that this nitrate bath can have any practical use. No way was found to overcome this deterioration of the baths.

A rough but not spongy deposit shows the exhaustion of some constituent of the bath. Warming the bath for a few minutes will bring more of the aloes residue into solution and correct any trouble due to lack of addition agent. Sometimes more acetic acid must be added to replace that which has been used in chemically dissolving the lead.

The paper which, in the absence of the author, had been read by Dr. Richards, was discussed by Messrs. Bancroft (who strongly suggested the application of broad fundamental principles to addition agent experiments), Lidbury, Bennett, and Addicks.

Electroplating with Cobalt

An elaborate paper, by Professor **Herbert T. Kalmus**, Mr. **C. H. Harper**, and Mr. **W. L. Lavell**, of Queen's University, described extended cobalt plating experiments made both in the laboratory and plating shops. The following general conclusions were reached from commercial tests:

Several cobalt solutions were found to be suitable for electroplating with cobalt under the conditions of commercial practice. Best among these are the following:

Solution I B:

Cobalt-ammonium sulphate, $CoSO_4.(NH_4)_2SO_4.6H_2O$, 200 grams to the liter of water, which is equivalent of 145 grams of anhydrous cobalt-ammonium sulphate, $CoSO_4.(NH_4)_2SO_4$, to the liter of water. Sp. gr. = 1.053 at 15° C.

Solution XIII B:

Cobalt sulphate $CoSO_4$	312 grams
Sodium chloride NaCl	19.6 "
Boric acid	nearly to saturation
Water	1000 c.c.

Sp. Gr. = 1.25 at 15° C.

Cobalt plates from these solutions, on brass, iron, steel, copper, tin, German silver, lead and Britannia metal articles, of different shapes and sizes, deposited under conditions identical with those met with in general nickel plating practice, are firm, adherent, hard and uniform. They may readily be buffed to a satisfactorily finished surface, having a beautiful luster, which, although brilliantly white, possesses a slightly bluish cast.

The electrical conductivity of these solutions is considerably higher than that of the standard commercial nickel solutions, so that other things being equal, they may be operated at a lower voltage for a given speed of plating.

Solution 1 B is capable of cobalt plating on the various sizes and shapes of objects met with in commercial practice at a speed at least four times that of the fastest satisfactory nickel solutions.

Solution XIII B is capable of cobalt plating on the various sizes and shapes of objects met with in commercial practice at a speed at least fifteen times as great as that of the fastest satisfactory nickel solutions.

Plates from both of these solutions on various stock pieces satisfactorily withstood the various bending, hammering and burnishing tests to which commercial nickel work is ordinarily submitted.

These two very rapid cobalt solutions are remarkable for their satisfactory throwing power. That is, they readily and satisfactorily deposit the cobalt in the indentations of the work.

These two rapid solutions operate at these high speeds in a perfectly still solution without agitation of any kind.

These solutions are both cleaner, that is freer from creeping salts and precipitated matter, than the standard commercial nickel baths.

The cobalt deposited at this rapid speed is very much harder than the nickel deposited in any commercial nickel bath. Consequently a lesser weight of this hard cobalt deposit will offer the same protective coat as a greater weight of the softer nickel deposit. Considering solution XIII B, operating at 150 amperes per square foot, on automobile parts, brass stampings, etc., a sufficient weight of cobalt to stand the usual commercial tests, including buffing and finishing, is deposited in one minute. With the best nickel baths it takes one hour at about 10 amperes per square foot to deposit a plate equally satisfactory. Therefore, the actual weight of metal on the cobalt plate must be approximately one-quarter that of nickel.

For many purposes, under the condition of these rapid plating solutions, one-quarter the weight of cobalt, as compared with nickel, is required to do the same protective work. Consequently, if nickel is worth 50 cents a pound, in the anode form, cobalt could be worth nearly $2 a pound, in the same form, to be on the same basis, weight for weight of metal. In addition there are other advantages of cobalt in saving of labor, time, overhead, etc.

A smaller plating room would handle a given amount of work per day with cobalt than with nickel.

With these very rapid plating solutions, by the use of mechanical devices to handle the work, the time required for plating, as well as the labor costs, may be tremendously reduced. Solution I B, and particularly Solution XIII B, are so rapid as to be revolutionary in this respect.

Obviously the cost of supplies, repairs, etc., would

be less with cobalt-plating than with nickel-plating, as the size of the plant for a required amount of work is less.

The voltage required for extremely rapid cobalt plating is greater than that for most nickel-plating baths; it is not so great but that the machines at present in use may in general be operated. For the same speed of plating the cobalt solution requires much the lower voltage.

For a given amount of work the power consumption for this rapid cobalt work is less than that for nickel. This is obvious, because the total amount of metal deposited in the case of cobalt is very much less, whereas the voltage at which it is deposited is not correspondingly greater.

Ornamental work on brass, copper, tin or German silver would require only a one-minute deposit. Even wares exposed to severe atmospheric influences, or friction, could be admirably coated with cobalt in bath XIII B in 15 minutes. The tremendous possibilities of this solution are not to be completely realized unless mechanical devices are applied to reduce hand labor to a considerable extent.

Thick deposits from these solutions are vastly superior to any that we have seen produced from nickel solutions. The tendency to distort thin cathodes is less pronounced, while electrotypes and electro-dies have been given a superior thick deposit in a most satisfactory manner. The lines were hard, sharp and tough and the surface smooth. Nickel does not equal cobalt for excellence of massive plates.

Many of these tests were passed upon by uninterested skilled mechanics at the plant of the Russell Motor Car Company, who invariably reported in favor of the cobalt as above.

Both baths I B and XIII B are substantially self-sustaining once they are put into operating condition, and the amount of ageing required to do this is very much less for them than that for the present commercial nickel baths.

The paper which, in the absence of the authors, had been presented by Dr. W. Lash Miller, was discussed by Messrs. Bennett, Fink, Watts, Proctor, Hogaboom, Blum, Chapin, Lidbury, Lukins, and Richards. While most of the electroplaters present thought that cobalt plating could not become practical on a large scale until the price would be down to that of nickel, others expressed the opinion that if the electroplaters would go on with cobalt and create a demand the price would go down.

After a hearty vote of thanks the meeting adjourned. The next meeting will be held in San Francisco on September 16, 17, 18, 1915, and it is proposed to hold joint sessions with the American Institute of Mining Engineers and the American Institute of Electrical Engineers.

The following is an alphabetical list of those who registered at the meeting:

Mr. and Mrs. Lawrence Addicks, Douglas, Ariz.; Wm. H. Adolph, Philadelphia, Pa.; T. R. Alexander, Jr., Philadelphia, Pa.; Walter Arthur, Philadelphia, Pa.; L. H. Baekeland, Yonkers, N. Y.; Samuel Barr, Philadelphia, Pa.; G. S. Barrows, Philadelphia, Pa.; E. H. Bedell, New York City; Wm. J. Bell, Philadelphia, Pa.; S. D. Benoliel, Philadelphia, Pa.; E. Blough, Pittsburgh, Pa.; Wm. Blum, Washington, D. C.; Marston T. Bogart, New York City; A. F. Borbeck, Philadelphia, Pa.; P. A. Borek, New York City; Mr. and Mrs. de Courey Browne, New York; A. S. Callen, Philadelphia, Pa.; H. C. Chapin, Cleveland, O.; Mr. and Mrs. H. B. Coho, Mt. Vernon, N. Y.; Jacob Y. M. Connell, Darby, Pa.; V. F. Cooper, Buffalo, N. Y.; Wm. A. Cowan, New York City; S. F. Cox, Princeton, N. J.; Mr. and Mrs. J. S. Crider, Cleveland, Ohio; R. A. Crider, Cleveland, Ohio; T. E. Crossman, New York City; Mr. and Mrs. W. R. Cymor, Cleveland, Ohio; N. E. Dabolt, Mt. Vernon, N. Y.; C. Dittman, New York City; Jos. L. Dixon, Philadelphia, Pa.; John V. N. Doer, Denver, Colo.; John H. Dorricoth, Philadelphia, Pa.; Miss Emlen, East Orange, N. J.; G. S. Ettla, Philadelphia, Pa.; J. Wm. Fehnel, Bethlehem, Pa.; C. G. Fink, East Orange, N. J.; Mr. and Mrs. F. A. J. Fitz Gerald, Niagara Falls, N. Y.; H. S. Flanegan, Mt. Vernon, N. Y.; W. S. Franklin, Bethlehem, Pa.; Francis C. Frary, Minneapolis, Minn.; F. S. Fuller, Schenectady, N. Y.; A. E. Gibbs, Buckingham Que.; Miss Mabel E. Gibbs, Buckingham, Que.; Mrs. W. T. Gibbs, Buckingham, Que.; H. W. Gillett, Ithaca, N. Y.; J. S. Glaze, Niagara Falls, N. Y.; Jac. S. Goldbaum, Norwood, Pa.; Jas. J. Guetz, Philadelphia, Pa.; R. E. Harrington, Newark, N. J.; August Heck, Philadelphia, Pa.; E. G. Henderson, Windsor, Ont.; Carl Hering, Philadelphia, Pa.; Edwin V. Hicks, Philadelphia, Pa.; J. Bennett Hill, Philadelphia, Pa.; A. G. Hinckley, Niagara Falls, N. Y.; H. K. Hitchcock, Pittsburgh, Pa.; Geo. B. Hogaboom, New Britain, Conn.; C. A. Holkesvig, Gibbsboro, N. J.; A. H. Hooker, Niagara Falls, N. Y.; Mr. and Mrs. W. F. Hubley, East Orange, N. J.; G. A. Hulett, Princeton, N. J.; O. Hutchins, Niagara Falls, N. Y.; Herbert E. Ives, Philadelphia, Pa.; J. E. Johnson, Jr., New York City; Roy Kegeneis, Philadelphia, Pa.; Mr. and Mrs. H. W. Kellogg, Niagara Falls, N. Y.; C. E. S. Kimer, Pittsburgh, Pa.; H. F. Kleinfeldt, New York City; Wilson Kutz, Philadelphia, Pa.; Edw. W. Lawler, Bayonne, N. J.; F. A. Lidbury, Niagara Falls, N. Y.; Charles F. Lindsay, Bridgeport, Conn.; Mr. and Mrs. L. M. Miller, Schenectady, N. Y.; W. Lash Miller, Toronto, Can.; H. S. Miner, Gloucester, N. J.; Wm. Roy Mott, Cleveland, Ohio; J. M. Muir, New York; John H. Müller, Philadelphia, Pa.; E. F. Northrup, Princeton, N. J.; N. Petinot, New York; Wm. Petinot, New York; Chas. H. Proctor, Arlington, N. J.; Jos. W. Richards, South Bethlehem, Pa.; E. G. Rippel, Buffalo, N. Y.; Howard S. Roberts (2nd), Philadelphia, Pa.; E. F. Roeber, New York City; F. W. Roller, New York; S. E. Ruder, Schenectady, N. Y.; L. E. Saunders, Niagara Falls, N. Y.; Carl G. Schlueederberg, Pittsburgh, Pa.; Irvin Scioba, Philadelphia, Pa.; Mr. and Mrs. E. M. Sergeant, Niagara Falls, N. Y.; F. T. Setchfield, Salt Lake City, Utah; John M. Shrigley, Williamson School, Pa.; W. Acheson Smith, Niagara Falls, N. Y.; Walter F. Smith, Philadelphia, Pa.; W. M. Snow, La Salle, Ill.; L. L. Summers, Chicago, Ill.; O. R. Sweeney, Philadelphia, Pa.; Walter T. Taggart, Philadelphia, Pa.; Eben T. Takamine, New York City; Johich Takamine, New York City; H. S. Taylor, Princeton, N. J.; F. J. Tone, Niagara Falls, N. Y.; Phil. Uhl, Philadelphia, Pa.; G. D. Van Arsdale, New York City; Mr. and Mrs. L. D. Vorce, Detroit, Mich.; D. E. Weintraub, Lynn, Mass.; T. A. Witherspoon, Washington, D. C.; W. R. Whitney, Schenectady, N. Y.; Hiram S. Wilkins, Philadelphia, Pa.; A. M. Williamson, Niagara Falls, N. Y.; C. A. Winder, Niagara Falls, N. Y.; Chas. Wirt, Philadelphia, Pa.; F. C. Woodside, Pittsfield, Mass.; Mr. and Mrs. J. A. Yunck, South Orange, N. J.

Metallurgical and Chemical Engineering in Great Britain

(By Our London Correspondent)

The British Aniline Dye Industry

The Prospectus of British Dyes Limited

On March 6 the prospectus of British Dyes Ltd. was issued to the public. The authorized share capital is £2,000,000 debentures (for which public subscription was invited) and £1,500,000 4 per cent mortgage debentures to be advanced by the Government. The prospectus follows closely upon the lines of the Government announcement in the House of Commons on the subject, to which I referred to in my last letter. The following points only need mention: (a) the articles of association provide powers for the appointment of committees, including an advisory committee "of persons conversant with the science and practise of dying to advise the directors." (b) If the provisional agreements as to the acquisition of existing dye producing concerns are carried out, their present chemists and staff are to be retained as far as may be expedient. (c) Priority of supply of the company's product is reserved for shareholders subject to their signing a five years' agreement "to take their supplies from the company in all cases where the company is able to provide the same . . . of good quality and suitable for the consumers' business, and prices are reasonable." The dividends payable on the ordinary share capital are to be limited to 6 per cent until the debenture capital is extinguished. There are two Government nominees on the Board of Directors, Sir Frank Adams and Sir Gilbert Claughton. The remaining seven directors are representatives of the industry concerned.

British Dyes Limited—Its Critics

Naturally criticism has not been stinted, and it has been leveled from many points. On the one hand comes the demand for a protective tariff to foster the new industry. On the other hand doubts are raised as to our capabilities to develop the industry on an adequate scale in a worryingly brief space of time.

Still, when all is said and done the scheme is one of many which has received the best measure of support. Sir William Ramsay has come into the field with a criticism directed at the compositon of the board of

directors and speaks strongly on the absence of the scientific element on the board. To a very large extent this is inevitable. In a new industry of this character we have yet to evolve the equivalent of the kings of our iron and steel industry of the past like Sir Lowthian Bell or Sir Henry Bessemer, or to mention one name only, Sir Robert Hadfield, of to-day.

In far too many fields here we recruit commercial men and financiers for the boards of directors, and eschew the scientist and man of practical and technical experience. The result of this segregation has been woeful. The scientist and man of practical and technical experience is too often a child in matters financial and commercial. The financier, on the other hand, lacks to an even greater degree that technical knowledge and the scientifically imaginative foresight which has done so much in other countries. With all our inherent ingrained conservatism, one cannot but believe that the new type will be evolved and that speedily. A certain racial adaptiveness will be moulded by the forces making for industrial and economic evolution which will give us the new type. Not, of course, so quickly as we need or as we desire. The trend towards it has been evident for some time, and during which there has been a marked tendency to take the scientist from the microscope and the laboratory and give him control of works and processes and a voice in shaping the administrative and commercial policy of his firm. The critics came dangerously near to wrecking the whole scheme. Important sections of the industry held aloof. The subscriptions initially received were disappointing. A public meeting of subscribers was called and as a result sufficient blocks of shares were taken up to permit of the company proceeding to allotment. The matter is now on the knees of the gods. We must wait and see what follows.

Market Prices, March, 1915

	£	s.	d.
Aluminium ingots, ton lots	85	0	0
Alum, lump, loose, ton	£5, 5 & 5	10	0
Antimony, black sulphide powder, ton	45	0	0
Borax, Brit. refined crystal, cwt	20 & 1	1	0
Copper sulphate, ton	29	0	0
Caustic soda, 70 per cent ton	10	2	6
Ebonite rod, lb	..	3	0
Hydrochloric acid, cwt	..	4	6
India-rubber, Para fine lb	..	2	5½
Mica in original cases, medium	..	3/ to 5	0
Quicksilver (Spanish), bottle	12	0	0
Sal-ammoniac, ton	49	0	0
Sulphate of ammonia, ton	14	0	0
Sulphur recovered, ton	8	0	0
Shellac, cwt.	3	5	0
Platinum, oz., nominal	9	5	0
Zinc, cwt., suplhate	..	8	0

Copper opened £64.12.6 and fell away till the 3rd, £63.2.6. On the 4th it revived to £63.15.0 and continued stronger to £67 on the 20th. A temporary drop due to stoppage of exports then took place, but the price quickly recovered to £68.7.6 on the 22nd and £69 on the 24th, since easing a little to £68.5 on the 24th and closes £69.2.6.

Tin opened £183, fell off to £180 on the 3rd, and then rose till £190 was reached on the 9th, and the same price after a slight decline ruled on the 12th and 15th. The price then dropped, being £171.10 on the 22nd and £169 on the 24th, and touching £165.15 on the 26th. It recovered to £171 on the 29th and closes £171.5.0.

Haematite opened 82/6 and remained this price till the 17th, when it marked 85/- and rose to 87/6 on the 22nd. Settlement, 95/-.

Scotch Pig was 63/- on the 1st and rather weaker till the 5th, when it touched 62/10½, 63/6 being reached on the 8th, and prices then became stronger to 64/10½ on the 12th and 67/4½ on the 16th, culminating in 69/1½ on the 18th. There was then a temporary decline, but recovery was made on the 22nd, and 69/6 reached on the 24th. Settlement, 75/4½.

Cleveland opened 57/1½ and declined till the 3rd 56/6, it then improved till the 9th 58/-, and dropped on the 10th to 57/0½. Recovering, it reached 63/1½ on the 18th and after a slight dip resumed this price, rising subsequently to 65/- (26th) and 67/5 by the 30th and closes 67/3.

English Lead opened £20.15 and was £21 on the 5th and £24 on the 17th, at which price it remains steady and closes.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Recovery of Mercury from Amalgamation Residues of Cobalt-Silver Ores.—In the amalgamation of high-grade silver ores and concentrates in strong cyanide solution, as practiced in the Cobalt district, Ontario, Canada, considerable mercury remains in the residues and becomes a source of serious loss. A method of recovering this mercury has been devised by Mr. E. B. Thornhill, of Cobalt, Ontario, and is in use at the Buffalo mill at Cobalt. In the April *Bulletin* of the Canadian Mining Institute Mr. Thornhill describes his process and gives some results of operation. His patent was reviewed in this journal, January, 1915, page 63.

After amalgamation mercury exists in the residues mainly as a mercuric sulphide and partly as elemental mercury. The process consists in leaching the mercuric sulphide from the residues by means of a caustic alkaline sulphide solution, and precipitating the mercury from solution by metallic aluminum. The reactions are thus represented:

$$HgS + Na_2S = HgS.Na_2S$$

$$3HGs.Na_2S + 8NaOH + 2Al = 3Hg + 6Na_2S + 2NaAlO_2 + 4H_2O$$

In operation, the residue in the pregnant cyanide solution is filtered on a Moore vacuum filter, and the cake thus formed is washed with water to remove silver solution. The filter basket is then immersed in a tank containing the sodium sulphide solution, and this solution is slowly drawn through the cake until the effluent shows only a trace of mercury. Usually one ton of solution is used per ton of residue. The filtrate is then agitated with metallic aluminum to precipitate mercury; the precipitate allowed to settle and the clear solution decanted. The precipitate is washed with water and dried, after which the fluid mercury is separated by raking the precipitate with a hoe. The remaining powdered material is retorted and the mercury condensed in the usual manner.

The strength of the solvent used in the filtering process is important. It has been found that a solution of 4 per cent sodium sulphide and 1 per cent sodium hydroxide gives best results. If weaker solution is used the quantity of solution must be proportionately increased, with the resulting necessity of handling the increased quantity of filtrate. Commercial sodium sulphide costs $1.25 per cwt. in barrels, f.o.b. Toronto.

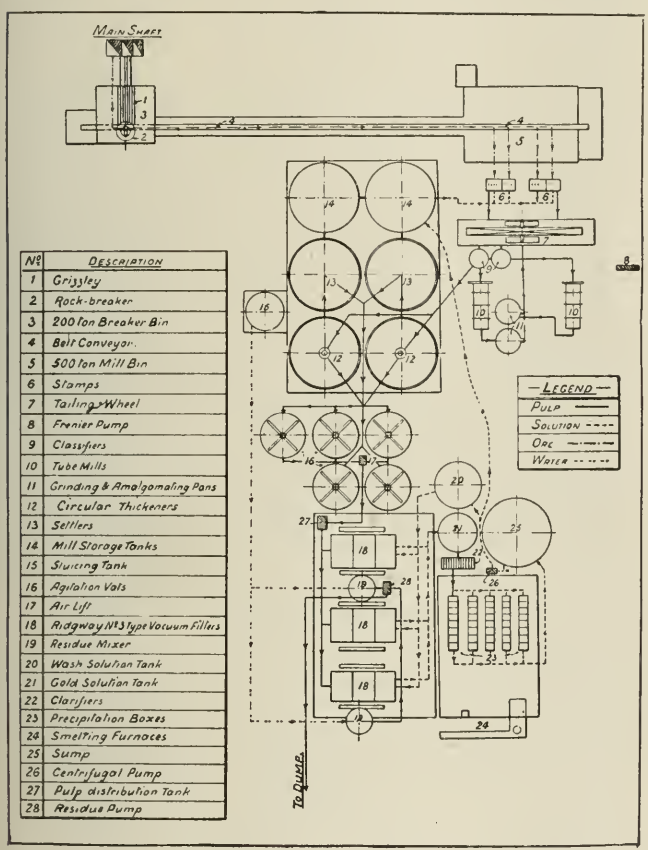
The precipitant used is a waste product from aluminum casting foundries. It is 75 per cent pure, the impurities consisting of copper, silica, wood, waste, grease, etc. The grease is burned off before using the aluminum. About ¼ lb. of the metal is used per pound of mercury precipitated.

Sodium aluminate does not increase in solution, some is removed as hydroxide with the mercury, some as calcium aluminate on the filter cake. By this precipitation of aluminium, caustic soda is regenerated, so that the consumption of this substance is reduced to one-tenth of a pound per pound of mercury recovered. Sodium sulphide also is regenerated, but there is a

mechanical loss of about 20 per cent in leaching, as no wash water is used.

From May, 1914, to date, 37,650 lb. mercury has been recovered at a cost of about 13c. per pound for labor and chemicals. The mercury recovered is of exceptional purity, the only determinable impurity being silver in the quantity of about ¼ oz. silver per ton.

Cyaniding at the Bullfinch Proprietary, Western Australia.—In the monthly *Journal* of the Chamber of Mines of Western Australia, for December, 1914, and January, 1915, Messrs. A. L. HAY and R. B. WILLIAMSON give many details regarding the mill and operations of the Bullfinch Proprietary Company. The ore is a mixture of both oxidized and sulphide material in about equal proportions. The metallic minerals are gold, galena, pyrite, marcasite and pyrrhotite. The galena is silver-bearing. Some native silver occurs in the oxidized ore. A flow-sheet of operations is shown in the accompanying Fig. 1. In brief, the treatment consists in breaking in a Symons gyratory; crushing by



No.	Description
1	Grizzley
2	Rock-breaker
3	200 Ton Breaker Bin
4	Belt Conveyor
5	500 Ton Mill Bin
6	Stamps
7	Tailing Wheel
8	Frenier Pump
9	Classifiers
10	Tube Mills
11	Grinding & Amalgamating Pans
12	Circular Thickeners
13	Settlers
14	Mill Storage Tanks
15	Sluicing Tank
16	Agitation Vats
17	Air Lift
18	Ridgway No. 3 Type Vacuum Filters
19	Residue Mixer
20	Wash Solution Tank
21	Gold Solution Tank
22	Clarifiers
23	Precipitation Boxes
24	Smelting Furnaces
25	Sump
26	Centrifugal Pump
27	Pulp distribution Tank
28	Residue Pump

FIG. 1—FLOW-SHEET BULLFINCH PROPRIETARY MILL

1200-lb. stamps; hydraulic classification, with tube-milling of the oversize; pan-amalgamation of the tube-mill discharge; thickening and agitation of the classifier undersize; filtration by vacuum in a Ridgway filter; and precipitation in zinc boxes.

With stamps dropping 7 in. at the rate of 106 per minute, and crushing through 8-mesh screen on three batteries and a 4-mesh on one, the stamp duty is 11.06 tons in 24 hours. The grading is as follows:

Mesh	Per Cent
+ 10	5.55
+ 20	16.25
+ 40	14.80
+ 60	10.20
+ 80	3.35
+ 150	7.25
+ 200	2.95
— 200	39.65
	100.00

A 50-hp motor runs the batteries which consume 66 hp, the motor showing no difficulty in handling this overload.

A tailing-wheel elevates the crushed product to the hydraulic classifiers. The wheel is 40 ft. in diameter and has 112 buckets each of 720 cu. in. capacity. The peripheral speed of the wheel is 400 ft. per minute. Rope drive is used, and a manila rope 6 in. in circumference lasts 60 days. Power consumption is 7.3 hp, the wheel lifting about 2500 tons of ore and solution per day.

Tube mills are lined with corrugated chilled-iron liners which last 380 days. Plain end liners last 120 days. The tubes are belt-driven by a 40-hp motor; power consumption varies from 36 to 45 hp. Consumption of pebbles is 2.5 lb. per ton of ore crushed at the stamps. Following are gradings of tube-mill feed and discharge:

Feed to Tube Mills		Discharge from Tube Mills	
Mesh	Per Cent	Mesh	Per Cent
+ 20	15.15	+ 20	.10
+ 40	15.70	+ 40	.60
+ 60	20.85	+ 60	9.69
+ 150	37.35	+ 150	47.98
— 150	10.95	— 150	41.63
	100		100

During the above grading tests the tubes handled each 102 tons of sp. gr. 1.74. Power taken was 41.7 hp.

Amalgamation follows tube milling, being performed in grinding pans, the overflow of which is returned to the tailing wheel. Cast-iron shoes and dies are used, the former lasting three months and the latter six. About 150 lb. of mercury per month is added to the pans, and 31.2 per cent of the total value of the ore is recovered in this operation. Mercury loss is 0.005 lb. per ton of ore milled. Pans are cleaned up once a month. Power consumption for two pans is 12.5 hp.

The overflow from the conical classifiers is thickened to 1.5 sp. gr. This pulp is agitated in mechanical agitators, 18 ft. diameter and 8 ft. deep, made of ¼-in. steel plate The stirring arms make 10.5 r.p.m. Power required is 1.6 hp for each agitator. Cyanide is added at the agitators, and 5 lb. lead acetate per charge to precipitate soluble sulphides. Charges are 44 tons of pulp. Time of agitation is 10 hours. The agitated pulp is air-lifted to a tank feeding the loading vats of a Ridgway filter.

The filters are of the movable type, each having two vats, one for pulp and one for wash solution. Time of cycle of operations is:

	Min.	Sec.
Cake formation	20	0
Transport from pulp to wash tank	1	13
Washing	35	0
Transport from wash tank, discharging, thence to pulp tank	2	12
Total	58	25

Extraction is 93.34 per cent.

The five agitators, three filters, three vacuum pumps, residue pump and one 3-in. centrifugal pump are driven by a 70-hp motor by means of ropes. Average horsepower consumed is 38.

In precipitation the zinc consumption is 0.22 lb. per ton of ore, and 1.3 tons of solution is precipitated per ton of ore treated. Precipitation boxes are cleaned once a month; the precipitate is treated with acid. Consumption of sulphuric acid is 0.113 lb. per ton of ore treated. The gold-zinc slime is roasted in muffles, fluxed and melted. Bullion is 908 fine, of which 755 is gold, 133 silver, and the balance copper, lead, etc. Bullion from amalgamation is 715 fine in gold, 230 in silver and 55 base.

The cost of treating 37,976 tons of ore, including proportion of general expense and realization charges, is as follows:

Process	Cost per Ton s.	d.
Rock breaking and conveying	0	4.21
Milling	1	10.58
Fine grinding and amalgamation	1	4.04
Settling and agitation	0	11.32
Filtration	0	11.2
Precipitation and smelting	0	4.49
Disposal of residue	1	3.05
Total	7	0.89

The cost of electrical power, including repairs and renewals:

Particulars	Cost per Hp per 24 Hours s.	d.
Labor	0	5.49
Stores	0	10.92
Total	1	4.41

Water costs 7s. per 1,000 gallons, and firewood, chiefly salmon gum, morrel, and gimlet, costs 7s. 6d. per ton.

Concentration

Butchart Riffle System.—Fig. 2 shows the plan of a deck of a concentrating table of the Wilfley type fitted with riffles of the Butchart system developed at Morenci, Ariz. The riffles are the subject of a paper presented at the February, 1915, meeting of the A. I. M. E. at

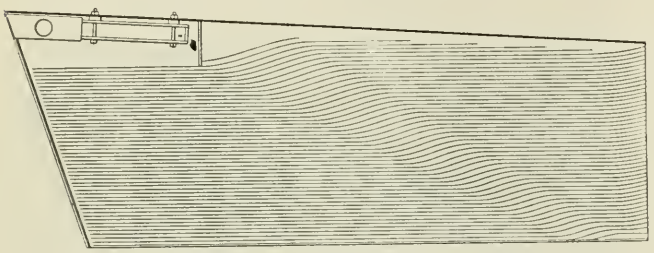


FIG. 2—BUTCHART SYSTEM OF RIFFLING

New York, by Mr. David Cole. The following comparison of the old and new systems of riffling is made.

"The old system accomplished stratification satisfactorily but has insufficient means for separating the strata. The new system not only stratifies the minerals but is provided with ample means for segregating and separating them. The old system has a single cleaning channel, or zone, consisting of the diagonal depression adjacent to and parallel with the successively advancing ends of the riffles, and this is easily overloaded in a way to defeat in large measure the object desired. The new system has as many individual cleaning channels as there are riffles upon the table, and these are not easily overloaded because they are filled in succession and back each other up.

"The old system is not adapted to the handling of very coarse table feeds, stopping for good work at about 2½ mm size, while the new system handles very large tonnages of what have hitherto been jig sizes, with a much simpler arrangement of machinery and with greatly improved general results.

"The new system eliminates the necessity of hydraulic classification beyond the desliming stage. Desliming or classification of any kind is not required on coarse feed because the table rejection is usually dewatered and reground for future treatment, and when either primary or reground material is to be handled it is necessary only to remove thoroughly the slime either in spitzslutte or drag classifiers. When classification is carried further than this too much of the fine sand is eliminated, with detrimental effect upon the work of the new table.

"The new system requires less water than the old. The water consumption of the new system is from 250 to 275 gal. per ton of feed; therefore, when these tables displace jigs the water consumption is reduced from 50 to 75 per cent, and when used instead of the old system it is reduced approximately 50 per cent.

"With these advantages the new system is very important in wet concentration, particularly where the ratio of concentration to be practiced is medium or low, and when used in conjunction with a successful flotation treatment of colloid overflows it makes possible the construction of a most desirable wet concentrating plant, adapted to large tonnages in relatively small space, and for a minimum capital expenditure per ton treated."

Mr. Cole's paper also contains some results of operation, and analyzes in detail the method of operation of both old and new systems of riffling.

Chemical Engineering

Commercial Glucose.—In *Science Conspectus* of the Mass. Inst. of Techn. (Vol. V, 1915, No. 1) George W. Rolfe discusses commercial glucose and its uses, "a much misunderstood and maligned product, necessary for certain food staples and a good substitute for more expensive ingredients." The basic process by which commercial glucose is made, is on the lines of Kirchhoff's old experiment (boiling starch with dilute sulphuric acid and neutralizing with chalk), but the methods are quite different. The "starch milk," a suspension of the granules in water, is pumped into large pressure boilers of gun metal and is cooked for about ten minutes with a few tenths of a per cent of hydrochloric acid under a pressure of about 50 lb. of steam. In percentages of total sugars and dextrines, the product contains 45 per cent maltose, 20 dextrose, and 35 dextrin. This composition has been found to be the most desirable for imparting to the product the properties most suited for a syrup which can be refined readily, and at the same time contain enough colloidal material (dextrin) to prevent its crystallizing at any concentration. This colloidal matter also renders the syrup capable of dissolving considerable amounts of cane sugar without crystallization. The rest of the dissolved substance of commercial glucose consists of 0.3 to 0.5 per cent of mineral matter. There is also about 0.08 per cent of nitrogen corresponding to five or six times its weight of organic substances from the gluten left in the starch. The glucose process does not end with the acid treatment of the starch and the neutralizing, as at this stage the dilute syrup is far from pure, containing oily matters from the corn, some undecomposed gluten and other impurities mostly in suspension. This liquor before it is concentrated to a syrup of about 80 per cent solids, undergoes a refining with boneblack closely resembling that of cane sugar, the apparatus being practically identical—filtering through bags and boneblack filters—but in the case of glucose all impurities affecting the quality of the syrup have to be removed or destroyed as there is no purification by crystallization. The following table, taken from an advertising circular of a manufacturer, shows in a concise way how the different parts of the corn kernel are utilized.

Parts of Corn Kernel	Composition	Products
1—Germ	Oil and Oil Cake	Corn Oil, Corn Oil Cake, Corn Oil Meal.
2—Endosperm (Body of the Corn)	Starch	Dry Starches, Dextrines, and by conversion, Corn Syrup [glucose] and Sugars.
	Gluten	
3—Hull	Bran	Gluten Feed.
4—Water added for steeping	Soluble Substances of Corn	

The oil is used principally for soap and for making vulcanized products used for rubber substitute. The oil-cake and meal from the cake are used as cattle feed. The gluten and bran from the starch, mixed with the soluble matters extracted by the water used to soften ("steep") the grain before grinding is made into "gluten feed" also for cattle. All these are valuable by-products for which there is a good market. The

starch in a moist state, known as "mill starch," is the raw material for making the various goods which are sold under the names of "glucose" ("corn syrup"); "corn sugar" ("grape sugar"), the latter a hard product which is largely composed of dextrose, but never known in trade as "commercial glucose" and little used as a food product; "dextrins," true adhesives which are usually made by roasting starch and entirely different in characteristics from the dextrin ingredient of commercial glucose; besides numerous "dry starches" used by laundries, confectioners, and in many other industries as well as for household purposes.

Glucose is now used in a legitimate manner to mix with cane-sugar syrup in the proportion of 85 per cent of glucose to 15 per cent of syrup, a little salt and sometimes vanillin being added to improve the flavor. The cane-sugar syrup is usually refinery molasses ("barrel syrup"), which imparts the principal flavor. These mixed syrups are sold openly as glucose or "corn syrups." Commercial glucose is used in large quantities in the manufacture of cheap jams and preserves. Apple cores and skins from fruit in its preparation for evaporation or preserving are the basis for most cheap jellies; the pecten substance and juice being extracted by the usual processes of jelly making and mixed with glucose and sugar forms a jelly material to which other fruit juices are added. The law requires such jellies to be plainly described on the label. By far the largest amount of glucose is consumed in the manufacture of candy, the peculiar properties of this syrup making it especially valuable in this industry, as has been explained. The requisite for most candy is that it should not "grain" (crystallize), and glucose, owing to its colloidal nature, is the most effective and wholesome substance to prevent this. Glucose is extensively used in industries not making food products. It is used in cheap soaps, for "filling" leather and tanning extracts, and as many of its uses in such industries are apparently for adulteration such practices have no doubt added to its reputation as the "champion adulterant."

Powdered Coal Plant at Anaconda

The use of powdered coal as fuel, restricted for so many years to Portland cement practice, is now spreading rapidly in metallurgical, chemical and industrial works. A description of a typical and commercially successful powdered-coal plant should, therefore, be of timely interest.

In our March issue (pages 181 to 185) we gave an account of the two admirable papers, presented by Mr. David H. Browne and Mr. Louis V. Bender before the American Institute of Mining Engineers on coal-dust-fired reverberatories at Copper Cliff and Anaconda.

From Mr. Bender's paper we take the following description of the powdered-coal plant at Anaconda and have added some notes and illustrations of the principal apparatus used.

At Anaconda the equipment is larger than is required for one furnace, but was installed with the idea in mind of finally equipping the entire reverberatory plant for coal-dust firing.

"The coal from the storage bin is fed into a 30 x 30-in. Jeffrey single-roll coal crusher, where it is reduced to 1 in. maximum size.

"The coal is then taken by a belt conveyor to the foot of an elevator passing over a Ding magnetic pulley, which removes any pieces of iron, bolts, etc.

"The coal is then elevated and fed by gravity into a 40 ft. x 6 ft. Ruggles-Coles drier. The drier consists of two cylinders, the one within the other. Blades of angle iron are fastened to the inner side of the outer cylinder and the outer side of the inner cylinder, so arranged that as the drier revolves the material fed into the space between the cylinders is lifted and dropped on to the inner cylinder and at the same time carried to the discharge end of the drier. The outer cylinder at the discharge end extends beyond the inner cylinder and has a revolving head riveted to it; on the inside of the head are buckets which lift the coal and deliver it out through the central casting. It takes a particle about 30 min. to pass from feed end to discharge end of the drier. At the feed end the inner cylinder is extended beyond the outer cylinder and, passing through a stationary head, is connected with the fire box.

"The gases are drawn from the fire box by means of a 72-in. Sturtevant fan, forward through the inner cylinder and back through the annular space between the cylinders to the stack. This exhaust fan is placed on top of the fire box and is connected to the drier by means of a 30-in. sheet-iron pipe. The fire box is fed with lump coal. The capacity of a drier depends upon the moisture in the coal and the speed of the fan. With Diamondville coal, we dry 18 tons per hour. During the month of September, 1914, we used 30 tons of coal to dry 1,984.77 tons of coal.

"From the drier the coal is elevated, conveyed by a screw conveyor, and discharged into a steel bin placed above the pulverizer, which is in a separate building from the drier. It is not well to have the pulverizer in the same building with the drier, for the reason that if an accident should occur, causing the coal to overflow, it might be drawn into the fire chamber of the drier and cause a fire, with possible injury to employees.

"The Raymond five-roller mill is used. It has an average hourly capacity of 4½ tons. At the top of the main shaft is a rigidly attached spider which rotates with the shaft and to the arm of which the five rollers are pivotally suspended by trunnions carried in bearings in the roller housing. Both upper and lower bearings of the roller journal are provided with long, removable, phosphor-bronze bushings. The rollers are made of cast iron with chilled faces. The grinding is accomplished by the force of centrifugal motion throwing the rollers outward against the steel bull ring. A plow is located ahead of each roller and constantly throws a stream of material between the face of the roller and the ring die.

"A fan is connected to this mill from which air is admitted underneath the grinding surface. The material is taken away by the air current as quickly as it is reduced by the rolls and blown into a 'cyclone dust collector' placed 20 ft. above the pulverizer. The mill is thus kept free of fine material. The collector is of galvanized steel, cone shaped, and has a return-air pipe leading from it to the housing around the base of the mill. A surplus-air pipe from this return-air pipe relieves the back pressure and is an outlet for any surplus air that may enter with the feed. An auxiliary collector is placed to receive the dust escaping through this surplus-air pipe.

"The finished product is discharged through a spout at the bottom of the dust collector, and is taken by a screw conveyor to a bin placed near to and above the furnace.

"The coal from the bin is introduced into the furnace by means of an air current delivered through five 'burners.' The air current is produced by a No. 11 Buffalo fan at a pressure of 10 oz., and, by means of a pipe carrying a nozzle, is introduced into a 6-in. pipe leading into the end of the furnace. The coal dust, fed from the bin by a screw conveyor, drops upon this

nozzle, which acts as a spreader, and is mixed with the air and taken into the furnace. A secondary air supply is obtained through the port holes through which the burners are projected into the furnace. These port holes are each 12 in. in diameter, which leaves an annular space 3 in. wide around each of the 6-in. pipes. By means of suitable dampers encircling the burners, this secondary air can be regulated. Another source of secondary air is through four openings between and above the burner ports, the size of the openings being regulated by putting in or taking out brick. The amount of coal fed is determined by the speed of the screw, which is easily regulated by a Reeves variable speed regulator. The entire grinding, conveying and bin system, from the drier to the burners, is air tight, as far as practicable, with the result that the entire plant is extremely clean and free from dust."

As to the excellent results obtained with this process of firing, the reader is referred to the further extracts from Mr. Bender's paper on page 184 of our March issue. In the present article we will give some further information on the apparatus used.

* * *

First, as to the **burners**, they are a special design gotten out by Mr. N. L. Warford of the Anaconda Copper Mining Co.

In Fig. 1, which shows the Warford pulverized-coal burner, A is the screw conveyor housing, B the mixing chamber housing, C the blast air nozzle, D the drive-

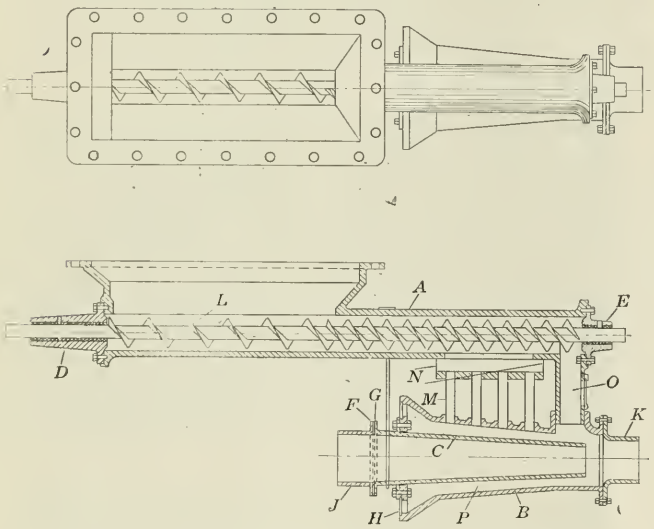


FIG. 1—WARFORD PULVERIZED COAL BURNER

end bearing of the conveyor, E the discharge-end bearing of the conveyor, F and G the blast-air control gate, H the free-air control valve or damper, J the sleeve to connect the blast-air pipe, K the sleeve to connect the discharge pipe to the furnace or fire box, L the screw-feed conveyor, and M connecting pipes between conveyor and mixing chamber.

The feeding device or control of quantity of coal dust required, consists of a screw conveyor enclosed in a dust-tight housing which is bolted to the bottom opening of the coal dust storage hopper, or bin through which the coal dust is fed into the screw by gravity. The screw carries the coal dust forward to the discharge end of the conveyor housing, where it is discharged into four receiving pipes, through a long narrow slot, and what does not go through the slot passes over and drops through a larger opening at the extreme end of conveyor housing.

The air and coal-dust mixing chamber consists of an outer housing through which a blast-air nozzle extends. The coal dust as it drops from conveyor housing through the slot is drawn into and through the four pipes onto blast-air nozzle, and the coal that does not go through slot drops on end of air nozzle, through the larger opening at end of screw conveyor, and all of the coal dust entering the mixing chamber is drawn to end of blast-air nozzle and blown into furnace or fire-box.

The principal claims made for this burner design are as follows:

The slot in the bottom of the discharge end of housing A causes the coal dust to flow in a thin stream, onto pipes M. Free air is drawn in at N and mixed with the coal as it goes through the pipes M, and is drawn onto and around nozzle C.

By having the end opening larger than the other pipes, any clogging of screw conveyor is prevented.

The pipes M, arranged as shown in the sketch, cause

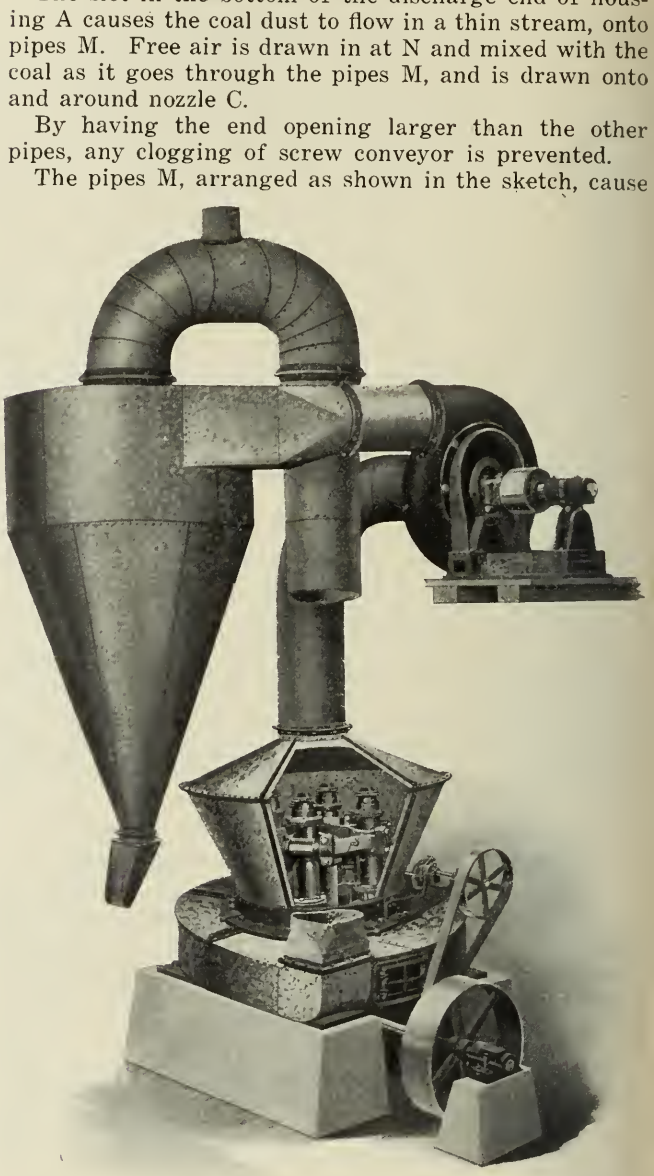


FIG. 2—ROLLER MILL WITH DUST COLLECTOR

the coal dust to get its first supply of free air as it is drawn through and the coal dust is broken up and mixed with this free air.

The free air damper or valve H, is so arranged that any amount of free air can be drawn into the mixing chamber P, up to its capacity.

The mixing chamber housing B, and blast-air nozzle C, are so arranged as to act as a siphon or injector, drawing in the free air, mixing it with the coal dust and injecting it into the furnace or fire-box, using pressure air as the power.

In general, the above claims assembled into one unit give the operator absolute control over both the coal dust and air, and thus enable him to secure thorough mixture of the air and coal dust, whereby a perfect

combustion of the coal dust in furnace or fire-box is obtained.

The Raymond five-roller mill and "cyclone" dust collector, which play quite an important part in the whole installation, are made by the Raymond Bros. Impact Pulverizer Co., of Chicago, Ill. (Fig. 2).

The mill consists of a number of perpendicularly suspended rolls, the capacity required determining the number of rolls, as the mill is built in sizes from two to five rolls. The rollers grind against a grinding ring; the material is thrown up between the roller and the ring by means of plows fastened to the slow-running central shaft, which only operates at a speed of about 115 revolutions per minute. In usual practice the speed of the mill pulley is about 240, with a system of gears of about two to one. The grinding is accomplished by centrifugal force, and as the rollers are free to swing towards the center of the mill, they will run over foreign matter, such as railroad spikes, without damage to the mill.

The mill will take coal crushed to pass a 1½-in. ring and in one operation reduce it to any fineness required from 95 per cent passing a 100 mesh to 95 per cent or 99 per cent passing a 200 mesh.

The fan, which is located above the mill, automatically separates the finely pulverized coal from the coarse and delivers it into the "cyclone collector," from which

FIG. 3—FAN FOR POWDERED-FUEL INSTALLATION

the air is returned to the mill through the return air housing, so that the same air is used over and over again.

On account of the suction of the fan, the mill is dustless in operation, and on account of the air separation a finer and more uniform powdered coal can be obtained.

It is also possible with this system to grind coal with more moisture, if necessary, although the coal should be dried, as it is cheaper to dry the coal on account of the fact that to grind wet coal decreases the output of the mill or increases the horse-power for the same output.

On account of the air separation the coal is taken away from the mill as soon as it is reduced to the necessary fineness. This fact, together with air separation, keeps the temperature of the mill and of the pulverized coal down to the lowest possible point, for which reason it is possible to store the powdered coal in bins for a longer time without danger of the coal taking fire from spontaneous combustion.

The Raymond mill with air separation will grind coal to any given fineness with about one-half the horsepower required for other systems and at the same time grind the finished product finer.

The Jeffrey single-roll coal crusher, which handles the coal coming from the storage bin, is built by the Jeffrey Manufacturing Company, of Columbus, Ohio. This is the type of coal crusher built by this company with a view to bigness, as the standard crusher of this type handles a 40-ton car of bituminous coal in 12 minutes, or more than three tons in a minute.

The drier used at Anaconda is built by the Ruggles-Coles Engineering Company, of New York City, and its construction is fully described in the excerpt from Mr. Bender's paper given above. The fan used in connection with the drier was built by the B. F. Sturtevant Company.

The No. 11 Buffalo fan, shown in Fig. 3, which is used for introducing the powdered coal into the furnace, is built by the Buffalo Forge Company, of Buffalo. It has a one-piece peripheral shell of heavy cast iron, to which side plates are fitted tightly and securely bolted. Either side plate may be readily removed, making it possible to take out the blast wheel when making repairs without entirely dismantling the machine. This fan is capable of delivering air against pressures as high as 18 oz. The one-piece peripheral shell does away with the putty joint, through which leakage is possible when the housing consists of two half shells bolted together along the peripheral line. The bearings are of the dust-proof oil-ring type, especially designed for high-speed service, the length being equal to over five diameters. An oil reservoir of large size is provided for the oil rings, making oiling necessary only at intervals of about once a month. The blast wheel consists of a heavy malleable iron hub with five arms upon which are mounted every alternate blade, there being ten blades in all.

Handling Condensation from Steam-Heating Plants

The Abbe Engineering Company, 220 Broadway, New York, have recently put on the market an automatic pump and receiver for handling the condensation from steam-heating plants. It includes a receiving tank with a special ball float inside of which operates the automatic electric switch. This automatically controls the operation of the pump. The float can be set to operate at any time: that is, it can be set to operate when the tank is half full, or three-quarters full of condensation. The pump returns the condensation to the boiler and it will pump against any pressure up to 30 lb.

The pump has its suction connected directly to the receiver into which the condensation from the heating plant flows by gravity, and the discharge from the pump connects to the boiler. This outfit is used in chemical plants, etc., to remove the condensation from any type of heating system.

The Abbe Engineering Company also has put a vacuum-heating pump on the market. This vacuum pump differs from the condensation pump inasmuch as this pump creates a vacuum in the heating system which allows the heating of largest buildings with about 1-lb. steam pressure, as the vacuum pump removes the air and condensation and returns condensation to boiler. With this latter system, vacuum valves are used on the radiators, and work automatically in connection with the vacuum pump.

Poidometer Test

The Schaffer Engineering & Equipment Company of Tiffin, Ohio, has just completed a series of tests on their poidometers for weighing and regulating the continuous flow of materials on conveyors, as described in our issue of March, 1914 (vol. 12, p. 206).

The test was made by marking the belt off in feet and placing an indicator so as to be able to get the exact travel of the belt. The machine was set to deliver 14 lb. of clay to the foot. A receptacle was placed under the delivery end of the machine and the machine was operated until it would run 6 ft. This would give 84 lb. of material. Each batch or the quantity on the 6 ft. was placed on a pair of very accurate scales and a careful record kept of each. Eighteen tests of this kind were taken. They produced 1517 lb. and should have produced 1512 lb., or, in other words, an accuracy of 99.67 per cent was obtained. The greatest variation between any tests was ½ of 1 per cent.

Fire clay was used in making this test, which was more or less sticky and was prepared so that part of it was fine material and part of it was very lumpy, some of the lumps being as large as 2 in. in size. The material was separated and fed into the machine in a divided manner, so as to produce as large a variation in the condition of the material as possible. By cubical test the material showed that it would vary in weight 20 per cent in accordance with its volume.

One test was made by using plaster containing hair, without any changes being made on the machine from its adjustment for running the clay, and a 99 per cent accuracy was obtained. It will, of course, be understood that this was about a 100 per cent change in the volume of the two materials. One test was made with 1 in. crushed limestone and an accuracy of 99¼ per cent was obtained without any adjustment being made on the machine.

Electric Steel Refining

The Snyder Electric Furnace Company, 53 West Jackson Boulevard, Chicago, is just completing the installation of a second 3-ton furnace for the Otis Elevator Company, Buffalo, N. Y. This furnace will have a basic lining, and will be used in the manufacture of refined steel castings. The contract for this second furnace was closed nine months after the first one was put in operation. It is expected that the new furnace will be running about the middle of April.

The Snyder Electric Furnace Company is also installing a small furnace for the Niagara Electric Steel Corporation, at North Tonawanda, N. Y. This furnace will be lined basic, and will have a daily output of 6 tons of refined steel.

In addition to these two furnaces, the Snyder company is just completing the installation of three different electric furnaces to be used in special chemical work. These will be in operation within the next few weeks.

The same company has recently issued a nicely illustrated pamphlet, entitled "A Better Steel at a Cost Lower Than Open Hearth for Equal Tonnages." The claim is made that the Snyder furnace produces steel of a quality better than crucible steel at a cost below that of an open-hearth furnace of equal capacity. To substantiate this claim, efficiency calculations are made. It is found that a combined gas producer and open-hearth installation has an efficiency of 7.8 per cent, while a combined gas-producer, gas-engine and Snyder electric-furnace installation has an efficiency of 8.6 per cent. The thermal efficiency of the Snyder electric furnace alone is stated to be a trifle better than 70 per cent.

Reliable simplicity is claimed for the Snyder furnace design, which is single-phase with a single electrode at the top. "Snyder 3-ton furnaces in regular daily operation are showing melting costs considerably under $20 per ton for metal in the ladle. One of these furnaces, in operation over a year, has in eight months' time only missed one heat, which it theoretically should have poured. This furnace runs only at night, using electricity purchased from the local power company on an off-peak schedule. The power is turned on at 7 p. m. and shut off at 6 a. m. During this eleven-hour period each night, four heats are made, melting from cold material. Occasionally five have been melted in the same length of time.

"With current at ¾ cent per kilowatt-hour, using a Snyder 6-ton unit, capable of producing ten heats in twenty-four hours, it is entirely practical to put steel into the ladle at a conversion cost equal to the usual records made with 50-ton open-hearth furnaces. This includes all items for labor, electricity, upkeep and repairs, and all fixed charges."

An Improved Diaphragm Material—Electro-Filtros

BY C. J. THATCHER

The lack of a satisfactory diaphragm material has probably hindered or prevented the commercial success of many promising electrolytic processes. At first thought it might seem that there should be no difficulty in obtaining cheap, porous or semi-permeable materials, suitable for prolonged commercial use as a diaphragm in any given electrolyte. Experience, or at least that of the writer, has not warranted any such optimistic view of the matter.

The readers of this journal need only be reminded of what the properties of a diaphragm material should be A diaphragm should be moistened by, but not be permeable to liquids except by diffusion, so that the anolyte and catholyte, or suspended solid constituents therein, will not commingle during considerable periods. A diaphragm is generally used to prevent such commingling of the anolyte and catholyte. For this reason a diaphragm material should either not be porous, or should have such exceedingly fine pores as to offer a high resistance to the passage of liquids therethrough.

But, on the other hand, a diaphragm material should offer little resistance to diffusion or migration of ions, so that the electrical resistance will not be so great as to be prohibitory. This requires that the diaphragm material should be somewhat porous.

These two fundamental considerations limit the range of materials suitable for diaphragms to those which are somewhat, but not very porous. But this is not all that a diaphragm should be. For commercial use it should be strong, of course, so as to stand the wear and tear of factory operations; and it should be permanent, that is, not disintegrated by the electrolytes or products of the electrolysis. If the material is not strong or permanent it should be very cheap, easily replaced, and readily obtainable in all shapes and sizes.

A moment's reflection shows that few, if any, available materials have possessed all of these requisite characteristics, and that the ideal diaphragm material for commercial purposes has not been obtainable. Porous earthenware or porcelain—the so-called Pukal ware—has perhaps approached nearest to the ideal of what diaphragm materials should be. Porous cups, with which all are familiar, are generally satisfactory for laboratory purposes, but not for large scale operations; for they are not cheap and are not available in commercially useful sizes and shapes. The writer at one time sought far and wide in this country, but without suc-

cess, to locate some concern which had, or could manufacture, suitably porous cups holding a gallon or more, or suitably porous earthenware plates 12 by 12 inches square or larger. Perhaps such materials are available abroad; they are certainly not in this country, particularly at the present time when many want them.

Other materials which have been used for diaphragms are paper, parchment and membranes; but these are not strong nor permanent enough for successful factory use in most electrolytes. Asbestos cloth is too porous, and often disintegrates rapidly. Wood can be used in a few cases, as it is in storage batteries, but not in strongly corrosive electrolytes, nor is it very effective as a separator of anolyte and catholyte liquids. There may be other materials which have been found satisfactory in isolated cases, but which the fortunate user has not been anxious to proclaim.

It may be safely said that in most instances the inventor or engineer who seeks to install, on a factory scale, electrochemical processes requiring efficient diaphragms, meets with a serious and often insurmountable problem when he casts about to secure a material suitable for his diaphragm.

Under these circumstances it is gratifying to be able to state that a material which appears to be highly satisfactory for most diaphragm purposes has been produced in this country. This new material is called "electro-filtros" and is being manufactured by the General Filtration Company of Rochester, N. Y. The writer has been using this material in small-scale factory operations for about three months under very severe conditions and feels justified in stating that it is not attacked or altered by dilute or strong acids, and that it has a permanent, low resistance but at the same time effectively and permanently prevents mixing of anolyte and catholyte liquids.

This materials is constructed of grains of finely pulverized, pure, crystalline silica, which are cemented together with a small percentage of a fused, silicious bonding substance by a process which has been patented. During the preparation of the material it is subjected to various treatments for which patent rights are also being obtained. The finished diaphragm material is white or nearly so, strong and rigid, of remarkable uniformity and resistance to acids, weak alkalies and neutral solutions. Electrochemists will perhaps be mainly interested in its strength, permanence, electrical resistance and effectiveness as a separator of anolyte and catholyte liquids.

As regards the strength of the diaphragm, it may be stated that it will stand any mechanical stresses to which it may be subjected. It will not crack nor break with a pressure of 90 pounds per square inch. A cross bend test shows that a plate 12 by 12 by 1½ inches, supported on ½-inch bearings, is capable of sustaining a load of 400 pounds applied to the middle.

In passing it may be stated that the material can be made of almost any thickness from ¼ inch up, but that it usually comes in plates ½ to 1 inch thick and which may be as large as 16 inches in one dimension. The standard shape is 12 by 12 inches, but of course the plates may be made larger or smaller as desired. It can also be made into tubes and cylinders of reasonable dimensions for exceptional processes or devices of special design. Large diaphragms can be constructed by fitting suitably sized plates in a supporting framework of suitable materials, and in which the plates may be cemented with sulphur, paraffin, retort cement, or other appropriate substances.

In the matter of permanence, electro-filtros leaves little to be desired, at least as far as use in acid and neutral electrolytes is concerned. It is not affected by any organic compound nor by any of the acids (excepting hydrofluoric) or their salts. The material is attacked by hot concentrated alkalies, but not by weak alkaline solutions, particularly at low temperatures. The electro-filtros plates which the writer has been using for nearly three months, in both dilute and concentrated acids at low and high temperatures, have not changed whatsoever during this time, as regards either their strength, permeability or electrical resistance.

The electrical resistance of this material depends largely, of course, on the electrolyte, but it is constant with any given electrolyte under constant conditions. As an illustration it may be stated that measurements recently made in an electrolyte consisting of about 60 per cent sulphuric acid and using, as the diaphragm, 12 by 12 inch plates, ¾ inch thick, which have been in continuous use during the past three months, gave the following results:

With the electrodes close against the diaphragm, *i.e.*, about ¾ of an inch apart, and a voltage drop of 5.6 volts between the poles, a current of 33 amperes flowed through the diaphragm. With the same electrodes, placed the same distance apart as before, and in the same electrolyte, but without the interposition of the diaphragm between the electrodes, a voltage drop of 5 volts gave a current of 43 amperes. That is, under the same conditions the resistance per square foot through the diaphragm was about .17 ohms, as compared with a resistance of .115 ohms through a volume of the electrolyte of the same dimensions as the diaphragm. In other words, the resistance through the diaphragm was less than twice as great as that of the sulphuric acid used as the electrolyte. This is practically the relative resistance which the same diaphragm showed when it was first used about three months ago.

Tests with other plates and in other electrolytes have sometimes given a higher relative resistance, amounting in one instance to as much as 3½ times that of the electrolyte; but the resistance has remained constant throughout the period of the test. For convenience most of these latter tests have been made with smaller electro-filtros plates, 3 by 3 by ½ inch dimensions.

With plates of this size, using, in one instance, concentrated zinc sulphate containing about 1 per cent sulphuric acid as the anolyte, and 20 per cent sulphuric acid as the catholyte, and with lead electrodes about 1¼ inches apart, a voltage between drop of 3.5 volts across the poles gave a current of .44 amperes at 12.43 P. M. and of .46 amperes at 5.49 P. M. The electrolysis had been continued during the intervening five hours, during which time the voltage remained constant. This gives a combined resistance through the electrolytes and diaphragm of about 7.6 ohms, for a 3-inch square plate ½ inch thick, which figures to 0.125 ohms per square foot. This same 3-inch square diaphragm was subsequently used for many hours as a separator between the above specified zinc sulphate and sulphuric acid electrolytes, without noticeable change in the electrical resistance through the diaphragm.

Since the anolyte and catholyte in this test were not of the same composition it was impossible to make a comparative test of the relative conductivities with and without the separator, such as that made, as above described, with the larger plate. But a similar, subsequent determination of the relative resistance of this small, 3-inch plate, when used as a diaphragm in dilute sulphuric acid, showed that the resistance through the diaphragm was 2 ohms. Through the same dilute sulphuric acid electrolyte, without the plate, the resistance was 1.26 ohms.

So that the resistance through the diaphragm with a given electrolyte was again less than twice that of the resistance of a body of the same electrolyte of the same dimensions as the diaphragm; and even after this dia-

phragm had been used for many hours as a separator in electrolytes containing a metal salt.

The behavior of this diaphragm material in weak alkaline solutions was determined by the following tests: A small 3-inch square diaphragm was placed in an electrolytic cell, both compartments of which were filled with about 20 per cent sodium hydrate solution. After standing for 24 hours the resistances through the diaphragm and through the volume of the electrolyte of the same dimensions as the diaphragm were determined as above described. The resistance through the diaphragm was found to be 3 ohms, and that through the same sodium hydrate electrolyte, without the diaphragm, 1.3 ohms. The permeability of the plate did not change during the period before specified. Tests showed that the caustic soda solution could be forced to percolate through the plate only very slowly, even under considerable pressure.

The foregoing figures show that the increase in the resistance of an electrolytic cell in which electro-filtros is used as a diaphragm is remarkably low. In electrolytic cells in which the electrodes are placed any considerable distance apart, or in which the electrolytes themselves have any considerable resistance, the increase in the resistance occasioned by the use of electro-filtros as a diaphragm is practically negligible.

For example, in any large electrolytic cell in which the electrodes are, say, 12 inches apart, and in which the total internal resistance of the cell is, say, 0.5 ohms, or $0.5 \div 12 = 0.04$ ohms per linear inch of the electrolyte between the poles, then the interposition of an electro-filtros diaphragm one inch thick between the electrodes would increase the resistance about $0.04 \times 2 = 0.08$ ohms. So that the total resistance between the electrodes, using the diaphragm, would be 0.58 ohms as compared with 0.50 ohms without the diaphragm, and the increased resistance due to the diaphragm would be practically negligible.

That electro-filtros diaphragms offer such a negligible resistance to the passage of the electric current is the more remarkable when viewed in connection with the impermeability of the material and its effectiveness as a separator between electrolytes of different compositions.

The following facts illustrate the impermeability of this diaphragm material, and show how far it prevents mixing of anolytes and catholytes.

One compartment of an electrolytic cell, provided with the 12 by 12 inch electro-filtros diaphragms which have been continuously used for the past three months, was filled recently with dilute sulphuric acid, the other compartment being empty at the start of the test. Since the diaphragm was placed vertically in the cell and the compartment at one side was filled with the dilute acid, there was a head of about 12 inches. The compartment filled with the dilute acid at the start of the test was about 12 by 5½ inches, and of course 12 inches deep. During the course of an hour the level of the acid fell ⅜ of an inch. Neglecting the leaking around the cemented edges (which was considerable), this indicates that only about 600 c.c. of acid could be forced to percolate through the diaphragm with a pressure of 12 inches of dilute acid in one hour. In a similar test of another diaphragm which had also been in continuous use for three months 650 c.c. of dilute acid was forced through the plate in one hour.

All who have had experience with the high rate of flow of liquids through diaphragm materials which have hitherto been available, will appreciate the advantage of a diaphragm material such as electro-filtros, which so effectively resists the passage of liquids through its interior, and at the same time possesses such a low electrical resistance as is shown by the tests previously described. Other tests, which it is unnecessary to describe in detail, show that this new diaphragm material has and retains the same impermeability to other electrolytes, both acid and alkaline, and neutral salt solutions.

These tests, it is believed, establish that electro-filtros is a permanent and effective diaphragm material; that it is not a filtering medium as are most diaphragm materials. This material is permeable, practically, only to diffusing liquids or migrating ions, which accounts for its low resistance to the passage of the electric current and its effectiveness in preventing commingling of the constituents of anolyte and catholyte liquors.

New Cupels

The Joseph Dixon Crucible Company, Jersey City, N. J., have put on the market what they term "Dixon's wonder cupels" for the use of refiners and assayers.

These are made in three sizes, 1¼ in., 1½ in. and 1¾ in. in diameter. They are not only strong and handable, but the absorption of silver into the cupel is much less than with cupels made from bone ash when used under similar conditions. They are made of such strength that they will not break in handling, and, in fact, meet exactly the requirements of the assayer.

The foreign manufacturing districts where clay and sand crucibles are made are in so deplorable a state at present that it has been a question for some time past if it would be possible for them to fill the demand of the laboratories and refineries of this country. The Joseph Dixon Crucible Company have now entered the field of assay crucibles, scorifiers and goods of a like nature, so that at present they have a fairly complete line of this class of goods. So far the sale has not been of so great a volume that they have been able to compete in price with foreign makers, but as scarcity increases and larger orders are secured there is little doubt but that as low, or possibly lower, prices can be made than imported goods of a similar nature now sell at.

The Schaeffer & Budenberg Mfg. Co., of Brooklyn, N. Y., has completed occupation of their new plant at Berry and South Fifth streets, near the Bridge Plaza (Williamsburg Bridge) in Brooklyn. The new building is a seven-floor reinforced-concrete structure with 10,000 square feet floor space to the floor. The company was founded in 1850 and has manufacturing plants in all parts of the world; one of their European factories has upward of 5000 employees. The Brooklyn firm was established in 1878. The products of the company are a complete line of thermometers, gauges, recording gauges, recording thermometers, counters, time recorders, indicating and recording tachometers, electric pyrometers, steam, oil and gas engine indicators, steam calorimeters, gauge testers and other instruments. One-half of an entire floor in the new main office is used as an exhibition room and equipped with a representative and complete line of the many instruments and testing apparatus made by the concern.

The **C. & G. Cooper Company**, of Mt. Vernon, Ohio, has issued Bulletin 54 on Cooper gas engines. It contains brief and well illustrated descriptions of some important gas engine installations recently made in this country. Among them are three 27½ in. x 42 in. twin tandem double-acting Cooper gas engines, direct driving low and high-pressure gas compressors, at the Taft, Cal., station of the Southern California Gas Company. These units deliver 30,500,000 cubic feet of free gas in 24 hours against a delivery pressure of 450 lbs.

What the Panama-Pacific International Exposition Means to the Metallurgical and Chemical Engineer

To be "educational" is the primary purpose of the Panama-Pacific International Exposition, and in the department of mines and metallurgy this motif is perhaps even more evident than elsewhere in the main palaces. It has been said that anyone engaged in or interested in mining and metallurgical work cannot visit the department devoted to these subjects without learning much that is of value. The general public, the young student contemplating his chosen profession, and the expert metallurgist backed by a lifetime's experience, were all planned for by those who arranged the

FIG. 1—EASTERN FACADE, PALACE OF MINES AND METALLURGY

features of the Palace of Mines and Metallurgy and exemplified therein "the natural mineral resources (metallic, non-metallic and fuels) of the world; their exploration and exploitation; their conversion into metal; their manufacture into structural forms and into raw materials for various industries."

Prof. Charles E. van Barneveld, chief of the department of mines and metallurgy, has announced it as his aim to illustrate within the palace devoted to these industries every mineral of economic importance, not merely by mineralogical and geological specimens, but by complete industrial exhibits, which begin with the undeveloped mineral resource, end with the article sold to the retail trade, and show, insofar as possible, the intermediate processes of mining, reduction and manufacture. Especial attention has been given to copper, lead and zinc, while the iron and steel industry is shown by a series of exhibits which Professor van Barneveld pronounces the most complete ever assembled.

The Palace of Mines and Metallurgy is located at the northeast corner of the main group of exhibit palaces facing on the Marina and lying between the Court of Abundance and the Avenue of Progress. The structure itself is rectangular in plan and covers an area of about 6 acres. At its center the roof curves upward into a dome 165 ft. in height and 130 ft. in diameter. Perhaps the most unique feature in arrangement is the idea of supplementing the area available for exhibits by utilizing space underground. A large area was excavated beneath the floor for a complete demonstration mine, where full-sized entries, drifts, stopes and rooms are shown with actual coal and ore faces in place, thus permitting the demonstration of various drilling, conveying, ventilating, pumping, and other equipment.

Throughout all the departments of the exposition a twofold object has been kept in view in the selection and arrangement of exhibits: first, to make the displays contemporaneous rather than historical, and second, to have machines in motion where possible, or to show processes by stages if feasible, so as to facilitate quickly acquiring a comprehensive idea of that which is presented. However, in the Palace of Mines and Metallurgy it has been made possible to go even farther than this. Hardly to be classed as an ordinary "moving exhibit" is the daily explosion which actually occurs in the mine beneath the Palace, followed by the hurried arrival of the mine-rescue and first-aid motor car, the testing of helmets in the foul gas within a glass smoke-room, and then the resuscitation of "victims" actually brought up from below. Ranking still higher in educational value is the experimental work constantly going on in the Government metallurgical laboratory established within the Palace in connection with an open metallurgical forum, which is expected to be a rendezvous for technical experts from all parts of the world.

The laboratory is something of a new departure as an exhibit in that original research is actually being conducted here at the same time that its arrangement and equipment is a display in itself. It is admitted that some interference may be occasioned by giving free access to the laboratory to all who may be interested in the work in hand, but from the number of experts who are expected to spend some time there during the exposition it is believed that the gain from their interest and suggestion will outweigh any hindrance that there may be. The model laboratory and the work under way there is in direct charge of Dr. F. G. Cottrell, chief physical chemist of the United States Bureau of Mines.

A schedule of research work actually being carried

FIG. 2—U. S. STEEL CORPORATION EXHIBIT IN MINING PALACE IN COURSE OF ERECTION

out in the laboratory includes both hydro- and pyrometallurgy, and embraces a general study of the chemistry of ore roasting. An important part of the pyrometallurgical work consists in a microscopic study of the ores under investigation. Tentative plans have also been laid for investigations of methods for the extraction of gold and silver from complex ores and of processes for the recovery of sulphur from sulfide ores. Microscopic examination of slags from copper and lead ores to discover how the metal losses occur are contemplated as well as studies of methods for simultaneously abating the smelter fume nuisance and recovering the materials carried by the flue gases. In the assay work planned, which is under the direction of Prof. G. H. Clevenger, of Leland Stanford, Jr., University, an ef-

fort will be made to develop and standardize methods at the same time that the program of tests is being carried out. In fact, this idea of attempting to standardize processes will be carried out in each department of the Bureau where experiment is conducted during the exposition.

It is not the purposes of this article to chronicle a partial list of the exhibits in the Palace of Mines and Metallurgy, but it is interesting to note that there are here no less than three moving-picture theaters, the better to exemplify processes and methods that could not be brought indoors. One of these, depicting every stage of the mining of iron ore and the manufacture of steel products, has a sufficient length of film illustrating the subject to operate steadily for eight hours without repeating. New details of the processes for treating copper and lead ores are presented, as well as the equipment of latest design used in connection with the recently developed processes. Concentrators, cyanide plants, classifiers and jigs are shown in operation, as well as models of several types of furnaces and converters. As indicative of the diversity of exhibits it may also be noted that a magnificent pipe organ is installed in such a way as to display the metal tubes as a manufacturer's product, at the same time that a musician charms the visitors with selections from the old masters.

It will be a surprise to many metallurgists to see the exhibits placed in the Palace by China and Japan. The display of the latter country is unique in that it shows manufactured articles of various metals, especially sheet copper and copper wire, made in Japan to be shipped to America for competition here with home-made products. The quality and variety of the samples exhibited are of great interest to manufacturers, when it is remembered that these products were made where the labor cost is the equivalent of only a few cents per day.

To recapitulate, the Palace of Mines and Metallurgy is a university where day after day may be spent with its staff of instructors, many of them technical experts, who are at the service of the visitor, ready to demonstrate process or method which is the last word in each particular field. The scope of the field covered is limited only by the range of the industry itself, and never before have such successful efforts been put forth to portray each detail and make readily accessible for the visitor's observation every process of the industries represented. In short, Vice-President Marshall's comment after visiting the exposition applies particularly to the Palace of Mines and Metallurgy. In the course of dedicating the exposition on behalf of the United States, he said: "I came to bear a message. I remained to become a student. This is the university of the world. It has a chair fully endowed to meet the wants and needs of each. The eye, the ear, the mind, the heart, the soul, each may have its horizon here enlarged. If there be anyone in America with a thirst for knowledge and for beauty and a longing for a liberal education such an one can here obtain it. Whoever can, even at a sacrifice of something which for the moment appears necessary, should come to see a real work of art never equalled even by a mirage."

The Sarco Engineering Company, manufacturers of the Sarco steam traps, Sarco vacuum valves and Sarco temperature regulators, have moved their offices to the new South Ferry Building, 1 State street, New York City.

Dr. **Emil E. Lungwitz**, Eastern representative of the Kelly Filter Press, has moved his office to 30 Church street, New York City.

Personal

Mr. **Philip Argall**, manager of Stratton's Independence, has sailed for London.

Mr. **James Aston** has resigned his position as professor of metallurgy in the University of Cincinnati to accept a position in the Bureau of Mines, investigating efficiency and safety in the steel industry.

Mr. **D. D. Berolzheimer**, librarian of The Chemists' Club since 1910 and organizer and manager of the "Library Service" of The Chemists' Club in 1913, has resigned to become librarian of the Barrett Manufacturing Company, New York.

Dr. **Lucien I. Blake** will deliver the Commencement address at the Colorado School of Mines, May 28. For several weeks past he has been lecturing at the school on Molecular Physics.

Mr. **James F. B. Bowles**, formerly physiologist in charge of water supply and purification plants at Panama, and recently sanitary expert with the U. S. expeditionary forces at Vera Cruz, Mexico, has associated himself with the Lederle Laboratories of New York City.

Mr. **E. M. Breed**, who for the past eight years has been District Manager of the Canadian Allis-Chalmers Ltd., with headquarters at Vancouver, has been appointed District Manager of the Pelton Water Wheel Company. He will continue his headquarters at Vancouver.

Prof. Joseph Daniels, of the mining department of the University of Washington, Seattle, will be in charge of the State's mineral exhibit at the Panama-Pacific Exposition.

Mr. **Tenney C. DeSollar**, chief engineer for the Quincy Mining Co., Hancock, Mich., has been spending part of a vacation visiting in Colorado and Missouri.

Mr. **John H. Hall**, 2 Rector Street, New York City, has discontinued his practice as consulting engineer and enters on May 1 the employment of the Taylor-Wharton Iron and Steel Company, High Bridge, N. J., as metallurgical engineer.

Mr. **J. E. Johnson, Jr.**, consulting engineer of New York City, made an address on modern power plants in the iron and steel industry before the State College Engineering Association at State College, Pa., on March 9, 1915.

Prof. **James F. Kemp**, of Columbia University, delivered the address to the graduating class of the Michigan College of Mines.

Dr. **Arthur D. Little** having addressed the American Chemical Society at New Orleans on "The Industrial Resources and Opportunities of the South" on April 1 repeated this address on April 5 before the Atlanta Chamber of Commerce and the Georgia section of the American Chemical Society at the luncheon given by the chamber.

Mr. **K. C. Parrish**, who had been in Colombia for two years developing a mining and metallurgical enterprise, is to return to the United States for a holiday.

Mr. **J. F. Mitchell-Roberts** has resigned his position as chief engineer to the Wilfley Mining Machinery Company of London, to take up private work; he will be absent from London for about nine months.

Mr. **William Russell**, special representative of the Dorr Cyanide Machinery in London, has been visiting the principal metallurgical centers of the United States.

Mr. **Howard See**, of the research department of the American Rolling Mill Co., gave a lecture before the Colorado Section of the A. I. M. E., in Denver, April 9. His subject was "Methods and Processes of Pure Iron Manufacture." The lecture was illustrated by lantern slides showing the production from raw material to finished product.

Mr. **Thomas M. Skinner**, Jr., metallurgist and assayer of Red Cliff, Col., has removed his office to Keeler, Cal.

Mr. **Robert C. Sticht**, general manager for the Mount Lyell Mining & Railway Co., has been elected president of the Australasian Institute of Mining Engineers.

Mr. **B. B. Thayer**, president of the Anaconda Copper Mining Co., is visiting the company's properties in Montana.

Mr. **E. E. Thum**, who has been superintendent of construction at Great Falls for the Anaconda Copper Mining Co., has resigned his position after eight years' service. He has been appointed professor of metallurgy in the University of Cincinnati.

Digest of U. S. Patents

Aqueous Bath, Electrodepositing, Aluminium
(*Complete prior to* 1903)

21,923, October 26, 1858, Luigi Ferrari Corbelli, of Florence, Grand Duchy of Tuscany, and Vincent Riatti, of the Duchy of Modena, assignors to L. F. Corbelli aforesaid.

Relates to the deposition of aluminium and manufacture of calomel. Several electrolytes are given, as follows: rock alum, 5931 parts, and chloride of calcium, 2076 parts; or the same quantity of rock alum with 2190 parts of chloride of sodium; or sulphate of aluminium, 4167 parts, and chloride of calcium, 2076 parts; or other aluminium salts may be substituted. The mixed, well-ground salts are dissolved in about two and one-half times their weight of water, filtered, and placed in a nonconducting vessel containing a layer of mercury on the bottom connected as anode by an insulated iron wire, the cathode being of zinc. A weak current is passed, chlorine being liberated at the anode forming protochloride of mercury, and aluminium separating at the cathode either as blackish powder or in a thin compact sheet.

140,924, July 15, 1873, John A. Jeançon, of Newport, Ky.

Relates to the deposition of aluminium, the electrolyte being any desired salt thereof, such as the sulphate, chloride, nitrate, acetate, cyanide, etc., or the double salt of aluminium and potassium, sodium, ammonium, or other metals, dissolved in distilled water and concentrated to 20 deg. Baumé (at 50 deg. Fahr.). The solution is heated to 140 deg. Fahr., a small quantity of free acid being present, which may be liberated by the addition of sulphuric acid. A plate of aluminium is used as the anode, the articles to be plated being first well cleaned and connected to the cathode. An electromotive force equal to four pairs of Smee's zinco-platinum plates, connected for intensity, is used. During the operation water and acid are added to replace that lost by evaporation, etc. If it is desirable to use solutions of aluminates as electrolytes, the solution must contain an excess of the alkaline hydrate, and the temperature at least 200 deg. Fahr.; the anode should be very small in proportion to the cathode, and is preferably of platinum. The battery power should be eight or ten large elements connected for quantity.

286,359, Oct. 9, 1883, William H. Williams, of Cincinnati, Ohio, assignor of one-third to Paul Mohr, of same place.

Relates to electrodepositing aluminium and prepares the electrolyte as follows: 2 lb. troy of dry clay or of oxide of aluminium, 2 lb. of sugar and 2 gal. of water are thoroughly mixed, allowed to settle, and filtered. To the clear portion is added 2 oz. of muriate of iron, sulphate of iron, or any other soluble salt of iron, and when the solution is effected, dissolve therein 32 oz. troy of tartaric acid. Then add slowly a strong solution of caustic potash, stirring constantly, until the tartaric acid appears to be exhausted. The mixture is then allowed to stand until the precipitate has settled, and filter. The solid portion remaining is a "salt" and may also be made by an alternative process, for which see the patent. Thirty-two ounces troy of the salt or of tartrate of aluminium are dissolved in 1 gal. of water with 28 oz. troy of cyanide of potassium and neutraiized with 32 oz. of tartaric acid. A precipitate is formed which after settling is filtered, the liquid being condensed by evaporation to the point of crystallization, allowed to cool and crystallize and the crystals collected and dried upon a sieve. To prepare the plating bath 9 oz. of the crystallized salt are dissolved in 1 gal. of water for depositing upon copper; and 16 oz. of the crystals to 1 gal. of water for plating upon iron, with 1 oz. of cyanide of potassium for each 4 oz. of the crystallized salt. As anode either platinum or carbon may be used. The strength of the bath may be maintained by immersing therein a porous cup containing some undissolved crystallized salt or oxide of aluminium; or an anode of aluminium may be immersed in the porous cup without the crystallized salt. The cyanide solution obtained just before crystallization may be used as the electrolyte if desired.

436,895, Sept. 23, 1890, John A. Jeançon, of Newport, Ky.

Relates to the electrodeposition of aluminium from an anode consisting of mixed aluminium and preferably about 30 per cent of carbon, the thoroughly agitated molten mass being cast into thin plates. The electrolyte consists of a saturated solution of persulphate of aluminium, that is, an acid sulphate of aluminium requiring a high temperature, preferably about 180 deg. to 200 deg. Fahr., to prevent crystallization. The current is of very low intensity but of great quantity. The process is said to produce a dense and compact deposit of aluminium which may be burnished and buffed.

577,186, Feb. 16, 1897, Caleb Grozier Collins, of Woodsburg, N. Y., assignor to Calvin Amory Stevens, of New York, N. Y.

Relates to the electrodeposition of aluminium and describes a two-compartment cell, the anolyte consisting of a solution of aluminium sulphate made by dissolving alumina in sulphuric acid of 45 deg. Baumé using a carbon anode or a dilute sulphuric acid with an anode of aluminium. The catholyte consists of a 20-deg. Baumé solution of potash to which is added tartaric acid or any other derivative of pure argol in the proportion of about two-tenths by weight of the potash used, there is then added about 2 lb. of phosphate of aluminium per gallon of the solution; when the phosphate is dissolved then add aqua ammonia of 26-deg. strength in the proportion of 3 per cent of the whole solution. Within the catholyte is placed the article to be electroplated.

A **2600-lb. silver nugget** was discovered March 23 on the Townsite property, Cobalt, Canada. The slab was approximately four feet square and ten inches thick. This nugget is much heavier than the famous Cobalt Gem nugget, but not so rich. It was uncovered a few feet below the surface while making an open cut on a vein on the Townsite property.

Book Reviews

Concentrating Ores by Flotation. By **Theodore T. Hoover.** 221 pages, 55 illustrations; price $3.75. London: The Mining Magazine. San Francisco: Mining Press.

To quote the preface, "this is a report of progress in a rapidly developing art". The author was for four years general manager of the Mineral Separation, Ltd., but states that the said company is not necessarily in agreement with all the opinions expressed in the book, "and, in fact, quite properly opposes some of the views set forth." Learning that his friends Sulman and Picard, with whom he had been professionally associated, are preparing a book on "Theories of Concentration Processes Involving Surface Tension," the author has refrained from giving any new and unpublished information of this nature. Aside from this, the reader will find the flotation methods thoroughly considered particularly in their historical, chronological and legal aspects and relations. It is a timely and high-grade book.

* * *

Mining Costs of the World. By **Edmond Norton Skinner** and **H. Robinson Plate.** 406 pages with maps and tables. New York: McGraw-Hill Book Company, Inc. Price (flexible morocco) $5.00.

These two mining engineers have laboriously compiled, for the benefit of engineers, managers, operators and students, from companies' annual reports, financial statements and direct communications, costs and other important operating data on 325 metal mines in different parts of the world. The book is therefore, in one way, not as broad as its title indicates. On the other hand, however, it is broader than its title, since it gives something more than costs; there are added in most cases brief descriptions of the mines, the methods of mining and reduction employed, and general information as to operating conditions. The whole makes a valuable reference book for economic geologists, mining engineers and metallurgists. The maps are poor, but the rest of the book is a credit to the publishers.

* * *

Iron Ores. By **Edwin C. Eckel.** 430 pages, 64 maps and diagrams. Price $4.00. New York: McGraw-Hill Book Company.

The book consists of three sections: I, the origin of iron-ore deposits; II, the valuation of iron-ore properties; III, the iron-ores of the world. Each section is handled in a masterly manner. Valuable chapters in Part II are those on prospecting and tonnage determinations, mining conditions and costs, and ore prices, profits and markets. In the last section the author shows a wonderful acquaintance with iron deposits almost all over the world; he criticises and revises many of the careless estimates made in the "Iron Ore Reserves of the World", printed by the International Geological Congress in 1910, and in particular he discusses most competently what should be called "ore reserves," actual and possible, and the effect of improved metallurgical methods in extending the limits of workable and treatable ore. No such masterful presentation of the subject has been published in any language, and we heartily congratulate the author on the great value of his work.

* * *

Assaying, in Theory and Practice. By **E. A. Wright.** 324 pages, 70 illlus. Price $3.00 *net*. London: Edward Arnold. New York: Longmans, Greene & Co.

"Assaying," says a technological dictionary of date 1846, is "the determining of the amount of gold or silver in an ore." Expanding with developing industries, it became "the determination of the amount of a useful metal in an ore." The subject has now become "dry assaying" and "wet assaying." The former connoting furnace methods, the latter such ordinary analytical methods as are suited to the purpose. The latter differs from analysis only in its singleness of purpose, namely, to single out, separate and determine the amount of the one useful metal.

Mr. Wraight taught assaying, in the broader sense of the term, for twelve years in the Royal School of Mines, London. The book is redolent of the ancient assay laboratory, and at its best when describing the older fire methods, although even here it is inferior to one or more American books which could be mentioned. In the field of "wet assays," where it is to be judged by the methods of advanced analytical chemistry, it is in many places antiquated. It is, moreover, fragmentary to an exasperating degree: no mention whatever is made of determination of, or even testing for, platinum or the platinum metals, in either the dry or wet way; recipes are put forth at times without attempting to explain their why or wherefore.

The practical part of the book is good, as far as it goes, but the work as a whole will be disappointing to those wanting a modern, complete and up-to-date book on assaying.

* * *

The Raw Materials for the Enamel Industry and Their Chemical Technology. By **Julius Grunwald.** Translated from the German, by **Herbert H. Hodgson** 226 pages, 21 illus. Price $2.75. London: Charles Griffin & Company, Ltd. Philadelphia; J. B. Lippincott Company.

This is the third work of Dr. Grünwald's which Dr. Hodgson has translated; the preceding ones were "Enamelling on Iron and Steel" and "Iron Enamelling and Tinning." The present book lays the foundation for these industries by discussing in great detail the character of the materials used in making enamels, their occurrence in nature and their preparation for the application by the enameller. There is little technical literature on this subject, although great advances have been made by the entrance of scientifically trained men into the business. The book treats of the chemical and mineralogical technology of feldspar, quartz, fluorspar, clay, borax, cryolite, pyrolusite, tin oxide, nickel oxide, cobalt oxide, soda, saltpeter, potash, enamelling pigments, and some other miscellaneous materials—all from the standpoint of their use in the enamel industry, but particularly as it has been developed in Germany and Austria-Hungary.

The work, besides being valuable to those making enamels cannot but be useful in progressive men in the ceramic industries, and will also interest students of the chemistry of easily fusible salts and salt mixtures, particularly the low fusing point silicates and slags.

* * *

Geschichte des Elektroeisens.—Von Dr. Tech. Oswald Meyer. 15 x 23 cm., 187 pages, 206 illustrations. Price, 8 marks ($2). Berlin: Julius Springer.

A careful compilation of the history of the electric furnace manufacture of iron, complete and well illustrated. It can hardly be called critical, since good, bad and indifferent furnaces and processes are described in somewhat similar and optimistic language. If read critically, however, no harm is done. A very complete table of 238 electric steel furnaces in operation or construction gives a vivid tableaux of the great development of the electric steel industry.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIII. NEW YORK, JUNE, 1915 No. 6

PUBLISHED MONTHLY BY THE
McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer.
239 West 39th Street, New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Colo.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for June, 1915

EDITORIAL:
The Ways of the Chemists ... 343
The Iron in Lake Ores ... 343
Flotation as a Conservation Measure ... 344
Spelter and Other Coating Metals ... 345
READERS' VIEWS AND COMMENTS:
Rapid Analysis of Bearing Metals and High-Copper Content Alloys. By Carlton G. Lutts ... 346
Bottle-Filling Alarm. By E. J. Hall ... 347
Carbon Determination by the Combustion Method. By C. H. Rich ... 347
The Western Metallurgical Field ... 348
The Iron and Steel Market ... 349
The Non-Ferrous Metal Market ... 350
Paint Remover Patent Decision Before Court of Appeals ... 350
International Engineering Congress ... 351
Western Meetings of National Chemical Societies ... 351
Exposition of Chemical Industries ... 351
Beta Iron, Satire Allotropique. By Albert Sauveur ... 352
Obituary, Franklin Guiterman ... 352
The Action of Certain Colloids on Ions During Electrolysis. By A. Mutscheller ... 353
Comparative Furnace Efficiency. By R. J. Weitlaner ... 357
Chemical Engineering in Nitrocellulose Manufacture. By S. L. Stadelman ... 361
Library Service Bureau of United Engineering Societies ... 366
The Relative Efficiency of Various Amalgams in the Recovery of Gold. By Francis A. Thomson and Robert Keffer ... 367
METALLURGICAL AND CHEMICAL ENGINEERING IN GREAT BRITAIN ... 370
Blast Furnace Plant Auxiliaries and General Arrangement. By J. E. Johnson, Jr. ... 373
The Chemical Industries of Germany. By Percy F. Frankland 378
SYNOPSIS OF RECENT CHEMICAL AND METALLURGICAL LITERATURE ... 387
RECENT CHEMICAL AND METALLURGICAL PATENTS ... 391
Notes ... 392
Fuel-Supply Contracts and the Progress of More Scientific Methods of Purchase and Control in America and Europe. By John B. C. Kershaw ... 393
Is Duplexing Slated for Assassination? By Joseph Peyton ... 397
Instrument Exhibit at San Francisco ... 398
Electric Steel in Germany and Austria ... 398
An Important Advance in Gas Producer Efficiency ... 399
Drop Forged Parts as a Substitute for Brass Castings ... 400
The Preparation of Metal Specimens for Metallographic Tests 400
Sprays for Cooling Water ... 401
PERSONAL ... 402
NOTES ... 402
DIGEST OF ELECTROCHEMICAL U. S. PATENTS ... 403
BOOK REVIEWS ... 404

The Ways of the Chemists

All roads lead to the Pacific Coast this summer and American chemists and chemical engineers have their choice. The American Institute of Chemical Engineers will meet in Los Angeles on August 18 and in San Francisco from August 25 to 28, the American Chemical Society in Seattle from August 31 to September 3, the American Electrochemical Society in San Francisco from September 16 to 18, simultaneously with the American Institute of Mining Engineers and the American Institute of Electrical Engineers, and during the following week, September 20 to 25, the International Engineering Congress will be held.

If in view of the inherent unity of all chemical endeavor it is an axiomatic rule that meetings of different chemical societies in different cities should not conflict in date, the corollary would seem to be that meetings in the same locality should be held simultaneously and at least in part jointly. Yet here we have a string of Pacific Coast meetings extending over six weeks. Such are the ways of the chemists.

But who should be blamed? Not the chemists in the first place. When the International Engineering Congress was organized the chemists were considered a negligible quantity and not taken into consideration; this was awfully narrow from an engineering standpoint. If the Chemical Engineers and the Chemical Society stay away from the Congress, it is their good right and affords them an opportunity to strengthen their own individuality. On the other hand, the American Electrochemical Society, unafraid of having its individuality swamped, will enjoy intimate intercourse with mining and electrical engineers and its members will be able to attend the International Engineering Congress. The intercourse of ideas should be mutually helpful and should emphasize that after all the idea of chemistry not being a vital branch of engineering is ridiculously out of date.

The Iron in Lake Ores

A very valuable compilation is annually made by the Lake Superior Iron Ore Association, showing the average iron content, and in some cases also the phosphorus, silica and moisture, in the Lake Superior ores shipped during the preceding season, the Bessemer and non-Bessemer ores of each range being averaged separately. These statistics are carried back to the year 1902. It usually occurs that when one becomes really interested in statistics he desires more, and we confess we should be very glad if these statistics ranged back so that one could note the average iron content in the year when it was highest. We cannot extrapolate, of course, but we may note that from 1902 the average

iron content of all the Lake ores shipped decreased from 56.2233 per cent iron, natural state, to 55.5049 per cent in 1903. From 1903 to 1904 there was an increase of 0.07 per cent, a temporary fluctuation due to the fact that 1904 was an "off" year in iron demand and only the better ores were shipped. In 1905 there was a loss from 1904 of 0.97 per cent, and in 1906 a further loss of 0.74 per cent. Since then the annual losses have been growing less and less, but what the averages were prior to 1902 one can only conjecture.

While the iron content of a given ore deposit is determined by geology, the average iron content of the ores shipped in a season is determined partly by commercial conditions. When demand one year is poor, only the richer ores are shipped, and the average iron content of the season's shipments is certain to show either a gain or a smaller loss than usual. Over a period of years the older and richer deposits are exhausted and other and leaner ore bodies are opened. Of Lake Superior ores there is no end, and while attempts are often made to estimate the total tonnage in the ground of "commercially available" ores one might almost as well essay to determine the volume of a blunt cone without the height being given. As the cutting plane were lowered the volume would rapidly increase.

Of the 1914 shipments the tonnage and average iron content was as follows, low grade, silicious and manganiferous ores being omitted from the reckoning:

	Bessemer		Non-Bessemer	
	Tons	Per cent	Tons	Per cent
Gogebic	2,067,627	54.4771	1,387,006	53.5142
Marquette	380,484	53.9746	1,676,825	53.0141
Menominee	59,380	56.9574	2,360,684	51.5970
Vermillion	741,224	58.4818	262,946	58.7976
Cuyuna	.....	.....	736,573	50.0926
Total old range	3,248,715	55.5773	6,424,034	52.5031
Mesabi	8,075,955	52.5751	12,726,990	49.5887
All ranges	11,324,670	53.3789	19,151,024	50.5663

In 1907 the base guarantees were revised, being reduced from 56.70 per cent to 55 per cent, natural state, in the case of Bessemer ores, and from 52.80 per cent to 51.50 per cent in the cases of non-Bessemer ores. Thus in 1914 the average of old-range ores, Bessemer and non-Bessemer, barely escaped falling below the base analysis, while the Mesabi ores averaged more than two units below the base guarantees, so that as a rule Mesabi ores did not sell in the market for the nominal prices, but had penalties attached.

The cost of making a ton of pig iron has been greatly increased in the past 15 years or so by the loss of so many units of iron, while as a partial offset there have been improvements in processes of manufacture. Freights paid make up so large a part of the cost of assembling the raw materials for a ton of pig iron that the field for refinements in manufacture is limited, for as the iron content goes down, the coke and limestone requirements increase still more rapidly.

While the average iron content of the Lake Superior ores has been decreasing year by year, the cost per ton of mining has been increasing, for the ores must be sought farther and farther underground as the deposits nearer the surface become exhausted. Thus year by year more engineering and metallurgical skill is called for by the iron industry.

Flotation as a Conservation Measure

It seems reasonably probable that the flotation process will ultimately be recognized as one of the greatest agents in the conservation of mineral resources. While its adoption by American metallurgists has been long deferred, to the surprise of foreign engineers who have known of its success elsewhere for the past decade, it is now springing rapidly into prominence. There is scarcely a mill of major or minor prominence at which the process is not under investigation, provided it seems at all applicable to the ore under treatment.

The conservation of mineral resources, as relating to preventable waste, is one of the most important phases of the whole conservation movement. Forests once destroyed can be replaced in time; impoverished soil can be restored to fertility, and the development of water power and irrigation can sometimes go hand in hand and become permanent agents for good. In ore treatment, on the other hand, particularly in ore dressing, that part of the valuable material which "goes down the creek" as slime tailing is usually forever lost. For this reason any means of preventing such loss is a true agent for conservation, and in this realm flotation shines as a brilliant achievement and promise. It is to-day the accepted method of slime concentration for certain ores.

Flotation on a commercial scale was first applied in this country by Hyde on the Butte & Superior zinc ores. Prior to the use of flotation at Butte & Superior, zinc recovery was roundly 60 per cent. For the year 1914, with flotation in use, the average recovery was 88.71 per cent, and in the first quarter of 1915 it was 91.32 per cent. Coincident with the higher recovery came an increase in the grade of concentrates. This increase in recovery from 60 per cent to 90 per cent, or roughly one-third of the present figure, was due largely to the use of flotation. In 1914 Butte & Superior produced zinc at the rate of 15 per cent of the entire zinc production of the United States, and if flotation is to be credited with one-third of the output, we see that at one mill only, flotation was responsible for the production of about 5 per cent of the total zinc output of our country. These are impressive figures, and they emphasize the importance of flotation as a measure of conservation.

The prospective results from flotation in copper concentration are equally tremendous. As shown elsewhere in this issue, the recovery of copper in 1914 at five of the large western "porphyry" copper properties ranged from 66 per cent to 70 per cent. These results were obtained by ordinary methods of wet concentration without flotation. At Inspiration, on the other hand, where flotation plays an important part in the milling scheme, the recovery from sulphide ore in the experimental mill last February was 90.3 per cent, or from 20 per cent to 25 per cent greater than at the five properties mentioned above. Inspiration has been experimenting with flotation since January, 1913, at which time no copper ore was being treated on a commercial scale by flotation in this country. The process has been developed to a point where a combination flow-sheet has been

adopted for the mill now under construction, which will have a daily capacity of 14,400 tons. Production is expected to commence in June.

The results obtained at Inspiration are at least suggestive of the improvement that will be made at other mills treating similar ore, and in which slime concentration has been effected on vanners. Flotation is undergoing experiment at these mills, and may be expected soon to augment the output of copper. If results can be obtained comparable to those at Inspiration, the percentage recovery will be raised from 65 per cent or 70 per cent to about 90 per cent. The Utah, Ray Consolidated, Nevada Consolidated, Chino and Miami copper companies produced last year a total of over 321,000,000 pounds of copper, operating at greatly reduced capacity for five months of the year. Their aggregate ore reserves amount to over 585,000,000 tons of ore, containing an average of perhaps 1.6 per cent copper. If the application of flotation in the treatment of these ores should mean an increased recovery of 15 per cent or 20 per cent, the net increase looms large indeed. It is true that a part of the tonnage mentioned contains some carbonate ore, and on this portion the recovery would be necessarily lower than on straight sulphide ore: but methods have been suggested and may be successfully applied to render carbonates amenable to flotation.

The foregoing relates only to a few of the largest and most important producers of zinc and copper, because they afford an opportunity to gauge the influence of flotation in the future. Added to these, it must be remembered, will be the numerous small producers scattered throughout the West, to whom flotation will bring an even greater measure of conservation, with attendant profit. It must be obvious that on the settlement of pending litigation over flotation patents, the process will receive an impetus that will reveal its true influence and claim for it the recognition it deserves.

Spelter and Other Coating Metals

On Tuesday, May 12, the prices of tin, lead, and spelter stood in a relation that had never before obtained in the history of the metal market. The cost of the terne mixture used in making terne plate was less per pound than the price of spelter. Tin was 38.50 cents, New York, and lead 4.20 cents, making a 70 per cent lead and 30 per cent tin mixture cost 14.49 cents, while spelter at St. Louis was 15 cents. Never before had the terne mixture been cheaper than spelter. The lowest annual prices of both tin and lead fell in 1896, tin being 13.24 cents and lead 2.98 cents, making the value of a 70-30 mixture 6.06 cents. In the same year spelter averaged 3.80 cents, or 63 per cent as much, and 1896 was not spelter's lowest year. Incidentally the same day, May 18, was memorable for spelter in that the metal reached a price precisely double the highest price ever attained prior to the recent rise. That high point, 7.50 cents, was reached in September, 1912.

Everyone now understands that the phenomenal advance in spelter is due entirely to the war, first because the war largely increased the demand for brass for cartridges, and second because the war shut off the exports of spelter from Belgium and Germany. The net effect upon copper produced by the war has been very much less marked, for while the demand is increased the American copper exports that formerly went to Germany have been shut off.

What level the spelter market may attain no one can venture to predict, for when once a market transgresses its former bounds precedents become practically valueless. There is no reason to assume that the recent advance represents only a temporary rise, for purchases of spelter have lately been made, at the high prices, for deliveries late in this year and even in 1916.

With this complete dislocation in the relationships between the costs of the different coating metals, the whole matter of the consumption of metal-coated steel is opened. Spelter for coating purposes may indeed become altogether unobtainable, and in any event the relative costs of metal-coated steels are entirely altered. In 1913 there was produced 808,818 gross tons of galvanized iron and steel sheets, chiefly steel, and 66,664 tons of formed products galvanized after forming, making a total of 875,482 gross tons. It is probable that for a large part of this material substitutes will have to be found. Naturally the preference will not run to the same substitute for all purposes. For roofing purposes the various prepared roofings, which in the past few years have made large inroads on the galvanized sheet roofing trade, will doubtless be more largely employed. Painted steel sheets may be employed for this and other purposes.

For a number of uses tin plate will prove an excellent substitute. The average price of tin the past month has been somewhat under 40 cents, but 40-cent tin as a coating metal is vastly cheaper than 15 or 20-cent spelter, because tin is readily applied at the rate of somewhat less than two pounds per base box of tin plate, 31,360 square inches, or a trifle less than 0.15 oz. per sq. ft., whereas for 28 gauge galvanized sheets almost 1.5 oz. spelter per sq. ft. is required. With 40-cent tin and 20-cent spelter the tin coating could be made five times the minimum and yet leave the cost of the coating metal per square foot the same, producing for certain purposes a vastly superior article. With terne plate the comparison is naturally much more favorable, lead being only a trifle more than one-tenth as costly as tin.

Some of the sheet galvanizers, in order to preserve at least part of their trade, are now disposed to turn to the lead-coated sheet. At various times in the past efforts have been made to place a lead-coated sheet on the market, but very indifferent success has been met. The conditions are now quite altered. The manufacturer can now afford to expend more money and effort to secure a satisfactory product, and the user can afford to pay a higher price. It is already known that two sheet mills in Ohio intend very shortly to place a lead-coated sheet on the market, as a substitute for the galvanized sheet they have been selling and are still endeavoring to sell, and information that may lead to the production of a more satisfactory lead-coated sheet than has yet been made is certainly at a premium.

Readers' Views and Comments

Rapid Analysis of Bearing Metals and High-Copper Content Alloys

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The author has found that the well-known method of Demorest, i.e., dissolving the alloy in concentrated H_2SO_4 and titrating with potassium permanganate and iodine for antimony and tin is inadequate for the many alloys containing considerable copper.

First, 5 per cent or more of copper severely affects the tin titration, and second, with copper over 75 per cent, as is the case in many alloys and scrap metal, the alloy is dissolved in sulphuric acid with difficulty, if at all.

For these reasons the following modification of that method is presented:

Method:—Place 1 gram of the drillings in a No. 3 beaker and add 50 c.c. of 1.20 HNO_3. After dissolving in the cold for a few minutes, place on hot plate and evaporate to about 10 c.c. Now dilute with water and boil a minute or so. After settling decant through a fine filter paper, leaving as much of the precipitate as possible in the beaker. Again boil the precipitate with HNO_3, dilute, filter all the precipitate off on the paper and wash well with hot water.

The filter paper containing all the antimonic and metastannic acids is put without drying into a beaker and 40 c.c. of H_2SO_4 (specific gravity 1.84) poured upon it. The filter paper is immediately blackened and partly dissolved. Now add a small quantity of water (about 15 c.c.) and place on the burner, watching that it doesn't boil over. (The addition of water at this point is done to prevent explosions when the $KClO_3$ is added.) Now add $KClO_3$. By repeated additions to the hot solution the carbon is completely burned out, leaving a colorless solution. If any precipitate still remains, a few minutes' vigorous boiling will dissolve it.

To the clear solution add about ½ gram of sulphur and boil one-half hour. Most of the sulphur will have disappeared at the end of that time, leaving the antimony in the "ous" condition and the tin in the "ic" condition. Cool, remove the ball of sulphur and dilute with three times its volume with water. Any lead that was carried down with the antimony and tin during the original treatment with HNO_3 will occur as $PbSO_4$ at this point and should be filtered on a gooch and weighed. (This usually happens with high tin and antimony alloys.)

The solution from the $PbSO_4$ filtration is heated to 60 deg. C. and standard permanganate run in to a deep pink color. Stir well and titrate back to colorless with standard ferrous sulphate. The iron factor of the permanganate times 1.076 gives the theoretical factor for antimony. It is always well to standardize the permanganate against C. P. antimony. The permanganate solution should be about 1/15 normal.

Tin.—After titrating, pour the solution into a large Erlemeyer flask, add one-third of the solution's volume of strong HCl(1.20) and place on hot plate. If the alloy does not contain 15 per cent or more of antimony add enough of a solution of $Sb_2(SO_4)_3$ to bring it up to that percentage. Heat to boiling and add short lengths of soft iron wire from time to time so as to evolve a rapid continuous stream of hydrogen. A stopper should be loosely fitted to exclude the air and so insure a complete reduction of the tin. Reduce in this manner three-quarters of an hour and then take off hot plate, cooling to tap water temperature with the stopper still in the flask.

When cool filter off the iron wire and precipitated antimony by means of suction through asbestos into a suction flask. Titrate immediately with 1/10 normal iodine to a blue color with starch. One c.c. of a 1/10 normal solution of I=0.00595 tin. This iodine solution is standardized against C.P. tin, reduced as above after dissolving the metal in concentrated H_2SO_4 (1.84).

Lead.—While titrating the antimony and tin, have evaporation of the nitric acid solution of lead, copper, etc., progressing after addition of 15 c.c. of concentrated H_2SO_4. When down to fumes cool and add twice its volume of water and filter off the $PbSO_4$ on a weighed gooch. Wash well and heat to dull redness for a minute or so over a Bunsen flame. This may be done to the best advantage by placing the gooch inside of a larger porcelain crucible. Weigh and $PbSO_4$ times 0.683 gives the percentage of lead. Any lead recovered from previous operations is added, giving total lead.

Copper.—Pass H_2S through the filtrate from the $PbSO_4$ determination, precipitating the copper as sulphide.

(A) If the alloy is of high copper content (around 75 per cent) dissolve the CuS in nitric acid, take down to sulphuric acid fumes and after diluting add ammonia to the neutral point and then 4 c.c. of HNO_3 (1.42). Electrolyze at three volts and 0.3 to 0.5 ampere, using revolving cathode, if possible.

(B) If, however, the copper content is low (around 10 per cent), some of the copper will have been lost previously in the analysis by being occluded with the tin and antimony precipitates and not recovered. A separate analysis is now necessary.

Dissolve 1 gram of the alloy in 40 c.c. of concentrated H_2SO_4 (1.84), boil a minute and cool. Dilute with twice its volume with water, let settle, and filter of $PbSO_4$ on a weighed gooch. Heat the filtrate to 60 deg. C. and titrate for antimony with permanganate and ferrous sulphate as described above. Checks may thus be obtained on both lead and antimony if desired.

To the solution now add 3 grams of tartaric acid, make slightly alkaline with ammonia, and add 3 c.c. of concentrated H_2SO_4. The tartaric acid holds the antimony in solution. (The solution at this point must have considerable volume to prevent the precipitation of ammonium salts.) Heat to boiling, add 2 grams of $Na_2S_2O_3$ and when dissolved add a solution containing about 1 gram of KCNS. Keep hot for fifteen minutes and then filter on a weighed gooch, wash well with hot water, dry at 110 deg. C. and weigh as CuCNS containing 0.5226 per cent of copper.

Iron.—This element occurs sometimes in scrap and should be determined at this point by precipitation with ammonia and either titrated or weighed as the oxide.

Zinc.—Boil off the H_2S from the copper sulphide filtrate and after confirming the presence or absence of iron, treat the solution so as to make it slightly acid. Heat and add 3 to 5 grams of sodium acetate and then an excess of a solution of $NaNH_4HPO_4$, $4H_2O$ and let settle. Filter the precipitated zinc ammonium phosphate on a weighed gooch, and after heating well over a Bunsen burner weigh as zinc pyrophosphate containing 42.9 per cent zinc.

METHOD FOR BEARING METALS CONTAINING ONLY Sn Sb AND Pb (DEMOREST)

Dissolve 1 gram of filings or chips in 40 c.c. of H_2SO_4

(1.84) and determine Pb and Sb as described under Copper (B). To determine the tin, take solution from the antimony titration and after reducing as described under the tin determination titrate with iodine.

Notes.—In spite of many authors' precautions against the oxidation of the reduced tin, no trouble has been experienced in this method. CO_2 has been found to be unnecessary. To make the $Sb_2(SO_4)_3$ solution used in the tin titration, dissolve 1 gram of C. P. antimony in 75 c.c. of boiling H_2SO_4 (1.84) and after cooling add 25 c.c. of water. 1 c.c. of this solution equals 0.01 gram of antimony.

The occlusion of copper in high tin and antimony and low copper alloys makes the above separate determination for copper necessary. The lead carried down is later recovered.

The large amount of $KClO_3$ necessary to oxidize the filter paper does no harm and serves to prevent the volatilization of the tin and antimony as their chlorides.

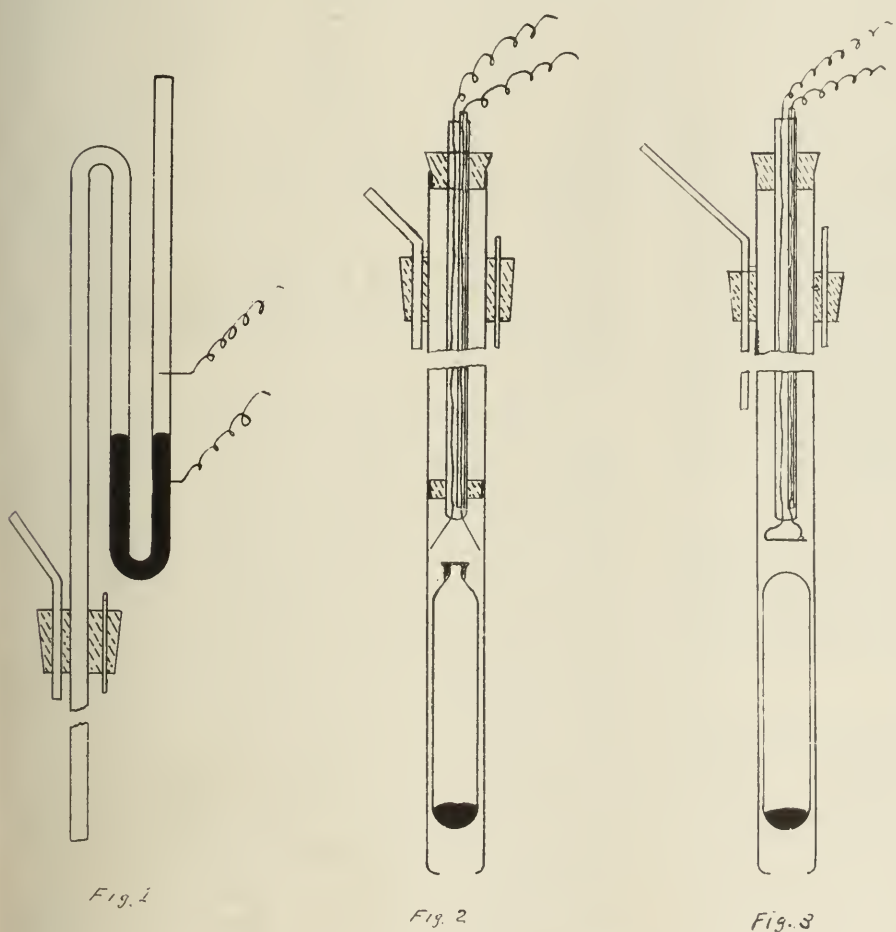
CARLTON G. LUTTS.

LYNN, MASS.

Bottle Filling Alarm

To the Editor of Metallurgical & Chemical Engineering:

SIR:—Keeping in mind water bottles while being filled from a still is positively a nuisance, and most people who have this duty to perform succeed in occasionally allowing them to overflow. To obviate this annoyance the alarms shown in the adjoining sketches were constructed. The leads are connected in series with a battery and bell.



FIGS. 1 TO 3—BOTTLE FILLING ALARM DEVICES

In Fig. 1 the center tube passing through cork reaches almost to bottom of water bottle. The angle tube is inlet and short vertical tube acts as a vent. As bottle fills pressure is produced, causing mercury to rise till contact is made, closing circuit. The contacts by this method are very satisfactory, but the mercury is apt to spill and the volume of air in tube varies with the temperature, causing alarm to ring with water at different levels under varying conditions.

To obviate these difficulties devices illustrated by Figs. 2 and 3, which are self-explanatory, were tried. The floats were made from ½ x 4-in. thin wall test tubes, weighted with mercury. In Fig. 2 the float is capped with a cartridge shell surfaced with silver foil. The wire contacts are of platinum soldered to copper leads with silver solder and fused into glass tube. The curved contact wire in Fig. 3 was rolled out thin to give it necessary flexibility.

These alarms have been in use for about three years, giving entire satisfaction.

E. J. HALL.

School of Mines, Columbia University, New York City.

Carbon Determination by the Combustion Method

To the Editor of Metallurgical & Chemical Engineering:

SIR:—The opening sentence of a communication under the above caption, in the February number furnishes an alluring text for a dissertation, but why go to the trouble—and incur expense and perhaps danger—in correcting a condition which need not or should not exist?

The simple expedient of lining the boat with powdered alundum, prevents the fused metallic residue sticking to the boat.

Boats may be made of any one of a number of different materials, but the writer recommends nickel of 22 gauge—B. & S. Blanks are cut from the sheet and stamped on a steel die; rough edges are then trimmed off and filed smooth. The boats cost a trifle under five cents each and average not less than 40 combustions.

The alundum is 60 mesh and lasts indefinitely except for such mechanical loss as is sustained in removing the fused residue. The residue is simply lifted from the bed of alundum and the boat is ready for the next combustion.

Both boat and alundum are ignited until free from carbon, before being used. The operator has his choice of a number of different materials for lining the boat but alundum is recommended.

This practice is not detailed as embodying anything new, but judging from the article above referred to, it may be new to some.

C. H. RICH.

Alan Wood Iron & Steel Co., Conshohocken, Pa.

Lead Poisoning in Manufacture of Storage Batteries is the subject of Bulletin 168 of the Bureau of Labor Statistics of the Department of Labor. The author is Dr. Alice Hamilton. It is thought that the dangers of the industry can be reduced to a minimum by installing hoods and exhausts to carry off fumes and dusts by substituting machine for hood work, by providing ample washing facilities for the workmen and insisting on strict cleanliness everywhere and by providing a separate lunch room as the only place where food may be kept and eaten.

The Western Metallurgical Field

The Porphyry Coppers in 1914

Among the annual reports issued by mining and metallurgical companies of the United States, none excel those of the great "porphyry" copper companies of the West. In addition to giving the fullest publicity to company affairs in a financial and commercial way, these companies include in their reports many interesting and valuable data on engineering operations, their cost and result. Several of them being under the control of the same group of men, their reports are uniform in arrangement and nature of data presented, thus facilitating easy comparison of the operations at different points. In the accompanying table we give the salient facts regarding the operations of the Utah, Ray Consolidated, Nevada Consolidated, Chino and Miami copper companies for 1914.

All of the companies mentioned operated at reduced capacity during the last five months of the year. The Utah company closed its Arthur plant entirely on August 6, 1914, but continued operations in the Magna plant. The latter handled an average of 12,223 tons daily throughout the year, and the former an average of 9214 tons daily for the period of operation. Recoveries were affected adversely by the presence of considerable quantities of oxidized copper minerals in the ores mined near the surface, but this condition will disappear as further progress in stripping is made. In spite of curtailed operations, however, the cost of production for the last five months of the year was 0.509 cents less per pound of copper than for the first seven months. This improvement was due partly to improvements in operation and partly to better grade of ore treated.

Operations of the "Porphyry" Copper Companies in 1914

	Utah	Ray Consolidated	Nevada Consolidated	Chino	Miami
Ore reserves, tons	342,500,000	74,765,789	41,020,296	90,270,155	36,500,000
Average content copper, per cent	1.45	2.214	1.75	1.75	1.85
Ore treated, tons	6,470,166	2,427,700	2,640,294	1,907,300	1,096,633
Average content copper, per cent	1.425	1.76	1.48	2.12	2.28
Gross copper production, lb	121,779,401	59,044,700	49,244,056	56,841,977	35,048,445
Average recovery, per cent	66.04	67.88	68.48	67.86	69.93
Average copper in concentrate, per cent	18.19	19.25	66.15	18.50	39.31
Average cost milling, cents per ton	35.36	49.88	.....	55.01	49.96
Cost of copper, cents per lb.[1]	8.131	8.839	10.16	7.68	6.46
	7.245	8.763	9.82	7.35	.....
Gold production, oz	34,729	.....	16,046	.....	.....
Silver production, oz	325,351	.....	49,631	.....	.....

[1]First figure based on net production after making smelter deductions and applying credit for gold and silver. In second figure credit is applied for all miscellaneous income.

At Ray the percentage extraction was increased, due to improved methods of operations, and cost of milling also was reduced. During the latter part of the year investigations were completed which will immediately insure lower cost of operation, higher grade of concentrate, increase in recovery and saving in smelting charges.

Nevada Consolidated completed the acquisition of the property of the Steptoe Valley Smelting & Mining Company, the latter company having been dissolved on Nov. 28, 1914. All operations of milling, mining and smelting are now conducted by the Nevada Consolidated company. Improvements at the mill consisted in adding Dorr thickeners and a new set of rolls. In the reverberatory smelting department there was a reduction in costs and fuel ratio. The capacity per furnace was increased from 481 tons per day in 1913 to 598 tons in 1914.

Chino installed an improved plant for enrichment of concentrates, thereby increasing the amount of gold in concentrates sufficiently to be credited under the smelting contract. The gold credit amounts to 2.71 cents per ton of crude ore treated, or 0.1 cent per pound of copper produced.

Miami completed changes in the mill, based on previous experiments, that will result in increased capacity and efficiency. The change consists mainly in finer grinding and additional table capacity on the sand floor, and improved methods of treating slime. The changes in treatment will result in a metallurgical efficiency as high as is possible with the present state of the art.

Flotation at Silverton, Colorado

The American Ore Flotation Company is a newly organized concern which contemplates the application of the flotation process in the San Juan district of Colorado. The company has leased the Silver Lake mill, near Silverton; has purchased the Ben Butler mining property at Mineral Point, above Animas Forks, and has taken options on the Mayflower in Arastra Gulch, and the Champion below Silverton. The mill is being equipped for flotation treatment, but will not be ready for operation until mid-summer. The promotion and operations of the company are reported to be in the hands of E. W. Weybright and D. L. Thomas, respectively, the latter having been previously an employee in the mill of the Butte & Superior Copper Company, where James M. Hyde installed and operated the first successful flotation plant in this country. Contrary to rumor, Mr. Hyde is in no way connected with the company at Silverton. The introduction of flotation in Colorado mills promises to be a large factor in increasing recovery and profits from low-grade mixed sulphide ores, particularly in improving former practice in slime concentration.

Marked Activity in the Joplin District

The continued strength of the zinc market is being reflected in unusual activity in the zinc-mining and milling districts of Missouri and Kansas. According to the Joplin *News-Herald*, the Joplin district produced 82,000 tons of zinc blende concentrates during the first four months of 1915. In view of the large number of mills being built or placed in operation, it is likely that the present rate of production is even higher. Profits for the first four months were not as large as can be anticipated at the present time. During the week ended May 9, deliveries of zinc concentrates were made on a basis of $75 a ton, 60 per cent metallic zinc. This price was previously reached in February for choice grades of ore, but the demand for second grades at that time was not good. The price of $75 represents an advance of $10 within two weeks, and the market is reported firmer than ever before in the history of the Joplin district.

New mills are being constructed and old ones rehabilitated. The Moreland custom mill has begun operations with a capacity of 150 tons per day. The mill of the Century company has been completed and is expected to be in operation shortly. Work has been resumed on the C. & S. No. 4 property after an idleness of fifteen months. The mill has a capacity of 250 tons a day. A new custom mill has been constructed in the Galena district, and nine concentrating plants are reported to have resumed operations at Aurora. A contract has been let

for the construction of a new 400-ton tailing mill for the Rollamo company north of Webb City. Near Stotts City a new 250-ton mill is being built on the Hill land. In the Lawton, Kan., district Greenfield & Lockwood have let a contract for the construction of a modern 300-ton plant.

Resumption of Copper Production in the West

It is reported that the Utah, Chino, Ray Consolidated and Nevada Consolidated copper companies are again operating at about full capacity. The improvement in the copper market and increased demand for the metal lead those conversant with conditions to believe that the increased production is warranted and that there is little or no danger of overproduction. The policy adopted by the companies last August, of retaining their working forces by offering employment at half time, has enabled them to increase production in a short period of time. The flexibility of their operations will enable these companies to curtail the output should the necessity appear.

Cyaniding at Cobalt

Prior to the outbreak of the European war many of the companies operating concentrating mills at Cobalt, Ontario, Canada, were either experimenting with the cyanidation of slime or had made definite plans for the addition of a cyanide plant to the existing mills. Among these the Cobalt Reduction Company had made many experiments which indicated the successful use of cyanidation. The plant has been constructed and was placed in operation about May 1. It will treat about 175 tons of slime per day, cyaniding that part of the pulp which formerly was treated by slime concentration, and producing bullion instead of slime concentrate. In addition to treating current slime from its own plant, the company will handle also the slime from the Cobalt Lake concentrator which will be delivered by a pipe line 1200 ft. long.

Company Reports

In the annual report of the Inspiration Consolidated Copper Company for the year 1914, General Manager C. E. Mills gives the following information under date of March 17, 1915. Copper production will begin during the month of June, the delay in the anticipated date being due to the change in milling plans and the adoption of flotation. The resultant combination flow-sheet involving the use of both ordinary water concentration and oil flotation will show an increase in copper recovery as compared with the use of either of the processes alone. Flotation testing was conducted during the entire year 1914, and at the same time experiments were made on grinding machinery. Parallel tests were run on various flow-sheets and five different flotation machines. The scheme finally adopted is, in brief, as follows: Crushing to 4-in. maximum size in gyratories, and further reducing to 1½ in. in Symons disk crushers. This work will be done at the mine. At the mill the ore will be ground to pass forty-eight-mesh by means of Marcy ball mills. The product will be treated in flotation machines. The tailings from flotation will be separated into sand and slime, the former being treated on concentration tables and the latter retreated in flotation machines. The concentrates will be dewatered in a filter plant.

The experimental plant showed a recovery during the month of February of 90.3 per cent of the copper occurring in sulphide form. The saving of oxidized forms of copper is not fully determined, but probably ranges from 20 per cent to 30 per cent. The average quantity of copper in oxide form in the ore milled last year was 0.16 per cent out of a total of 1.52 per cent copper. In such ore a recovery of sulphides of 86.7 per cent would correspond to a recovery of total copper of about 80 per cent. During 1914 the mill treated 172,722 tons of ore averaging 1.52 per cent copper. Inspiration concentrates will probably contain from 28 per cent to 32 per cent copper, and contain sufficient sulphur to make a suitable grade of matte in smelting. The mill will consist of eighteen sections, each of 800 tons daily capacity. The first nine sections are expected to be completed simultaneously, and the others before the end of this year. The transfer of the property of the New Keystone company to the Inspiration has been effected. Total ore reserves of Inspiration are estimated as follows:

	Tons	Per cent copper
Sulphide ore	46,252,000	2.01
Low sulphide material	28,698,000	1.26
Oxidized material	17,460,300	1.31
Mixed carbonate and sulphide	4,732,700	1.31
Total and average	97,143,000	1.63

The Iron and Steel Market

Developments during May in the steel market proved unexpectedly favorable. As noted in our review a month ago the future of the steel market hung in the balance. The improvement that had occurred during three or four months preceding had not continued through April and unless fresh favorable developments occurred conditions were likely to become distinctly less favorable. When the steel market is bad it may remain continuously bad and when it is good it may be continuously good for some time, but at a midway point it never halts; it must always be swinging towards the one extreme or the other.

The favorable developments in May were distinctly along two lines, export demand and railroad demand. Accurate details of export buying are largely lacking, partly because the orders are largely for war purposes, but it is known that many orders have been placed, others being still in the market, for 10,000-ton and larger lots of steel, chiefly in the form of merchant rounds for rifles and for shrapnel. Apart from war munitions, there has been Russian buying of both freight cars and rails, 9000 cars being placed in the United States and 6000 in Canada, with 7000 still to be placed. Rails purchased by Russia already exceed 50,000 tons, and statements of the total tonnage to be bought range from 100,000 to 500,000 tons.

Apart from 2500 freight cars placed at its Altoona shops the Pennsylvania railroad system has bought 14,000 cars and is understood to have arranged for 138,000 tons of rails and about 200 locomotives and about 200 passenger cars, some of the locomotives to be built in its own shops. The total tonnage involved in all these purchases is not far from 550,000 gross tons.

There has been tentative inquiry in the market for 15,000 or more cars for other roads, and a few locomotives. It is expected that the liberal buying policy adopted by the Pennsylvania will cause other roads to purchase more freely.

March exports of iron and steel totaled 175,000 gross tons, for commodities returned by weight, and with steel involved in machinery and other manufactures exported the exports may have represented 10 per cent of the steel industry's capacity. The export movement has undoubtedly increased since March and June exports may easily represent 15 per cent of capacity. In the early months of the year railroad material shipped probably did not exceed 5 per cent of capacity, but there are distinct possibilities that within a month or two railroad material may involve 15 per cent of the capacity. With such increases the recent operating rate of

70 per cent of capacity may mount to well above 80 per cent, or to a point at which the supply of labor may prove to be an important element. It is doubted whether the steel industry could find sufficient labor to operate at capacity on short notice, seeing that increases in steel demand are naturally attended by more employment outside the steel manufacturing industry.

Fabricated steel contracts let in April are reported at 107,500 net tons, against 110,000 tons in March. The monthly average in the seven months preceding was but a trifle above 50,000 tons, so that the March and April showings, while low compared with normal times, represent a great improvement.

Pig Iron

The consumption of merchant pig iron has been increasing, but very slowly. There is somewhat freer buying, but scarcely in larger lots, for given periods, than formerly. A few idle merchant furnaces have been blown in, but the total increase in production is small. It is the general opinion that few more idle stacks will be gotten into blast unless materially higher prices are offered for iron. Pig iron prices have been phenomenally steady for a long time, at low levels, but in some quarters there is an expectation that a phenomenal advance may occur within a few months to break the monotony. In the past five months the average price of all descriptions of pig iron has not varied by 25 cents a ton, but conditions are perhaps such as to encourage a very sharp advance, once one is started. Southern iron is definitely higher than a month ago, by fully 25 cents a ton. We quote No. 2 foundry, delivered Philadelphia, $14.25 to $14.50; f.o.b. furnace, Buffalo, $13; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13; f.o.b. Birmingham, prompt, $9.50; third and fourth quarters, $9.75 to $10; at valley furnaces, 95c higher delivered Pittsburgh; Bessemer, $13.60 to $13.75; basic, $12.50 to $12.65; No. 2 foundry, $12.75 to $13; gray forge, $12.50 to $12.75; malleable, $12.75.

Steel

Fresh market transactions are very limited, consumers being covered by contracts on which occasional private adjustments are made. Prices are largely nominal at $18.50 to $19 for billets and $19 to $19.50 for sheet bars, at maker's mill, Youngstown, and at about 50 cents higher at maker's mill, Pittsburgh, with forward deliveries commanding somewhat higher prices. Rods are firm at $25, Pittsburgh.

Finished Steel

Demand for merchant bars has been excellent, as reinforced by the requirements for war purposes, and prices are strictly maintained. Plates continue weak. Galvanized sheets were advanced by the American Sheet & Tin Plate Company on May 17 from 3.40 cents to 3.60 cents, but only limited tonnages were sold at the new price, and the extreme scarcity of spelter makes it probable that further advances will occur, if indeed galvanized sheets do not disappear entirely from the market. The decrease in galvanized sheet production has caused more active competition for black sheet orders, and the black sheet market is weaker if not actually lower. On May 1 the National Tube Company advanced steel pipe, boiler tubes and line pipe by one point or about $2 a ton, other makers as a rule following the advance.

Current quotations are as follows for ordinary deliveries and are f.o.b. Pittsburgh unless otherwise noted:

Rails, standard sections, 1.25c for Bessemer, 1.34c. for open-hearth, f.o.b. mill except Colorado.

Plates, tank quality, 1.15c. to 1.20c.

Shapes, 1.20c. to 1.25c.

Steel bars and bands, 1.20c to 1.25c., base; hoops, 1.25c. to 1.30c., base.

Iron bars, 1.20c. to 1.25c., Pittsburgh; 1.17½c. to 1.22½c., Philadelphia; 1.15c. to 1.20c., Chicago.

Sheets, blue annealed, 10-gage, 1.35c.; black, 28-gage, 1.80c.; galvanized, 28-gage, 3.60c.; painted corrugated, 28-gage, 2.00c.; galvanized corrugated, 3.65c.

Tin plate, $3.10 to $3.20 for 100-lb. coke.

Steel pipe, 79 per cent off list.

Steel boiler tubes (less than carloads), 3½-in. to 4½-in., 74 per cent off list.

The Non-Ferrous Metal Market

During the month that has elapsed since our last report the market for lead has remained about stationary, while tin has receded. Spelter, on the other hand, has had a remarkable rise, and copper also has advanced. The demand for all metals continues strong and the prospect seems good for continued high prices.

Copper.—Early in May the price of electrolytic advanced to 18.30 @ 18.80 cents, New York, but quieted later to about 18.50 @ 18.60. Some sellers continued to ask up to 19 cents, but did little or no business in competitive markets. The demand for copper continues good and some very large orders are pending.

Tin.—This market has declined steadily during the month, and is generally quiet. May tin is quoted at about 40 cents, New York.

Lead.—Business continues fair, with apparently ample supply to meet the demand. Inquiry for military purposes lends interest to the market. New York lead is quoted at 4.20 @ 4.25 cents, with St. Louis at 4.12½ @ 4.15 cents.

Spelter.—After receding somewhat from its previous high level of prices, this market experienced a remarkable rise in the face of a comparatively light domestic demand. Smelters are being operated to capacity but have no stocks and are unable to produce enough for immediate needs. The latest quotation is 12½ @ 13½ cents, St. Louis.

Other Metals.—Aluminium is in greater demand and the New York quotation is firm at 19½ @ 19¾ cents for No. 1 ingots. Prices for antimony have risen again in the face of decreasing supply. Ordinary brands are quoted at 35 @ 37 cents, with special brands at 40 @ 45 cents. Quicksilver is somewhat higher, bringing $74 per flask of 75 lb., New York.

Paint Remover Patent Decision Before Court of Appeals

The decision[1] of the United States District Court, Southern District of New York, in the suit of the Chadeloid Chemical Co. against the Wilson Remover Co. and J. McN. Wilson, in favor of the complainant and upholding the Carleton Ellis patent 714,880 of December 21, 1902, has been upheld by the United States Circuit Court of Appeals (Judges Coxe, Ward and Rogers).

From the decision of the Court of Appeals, written by Judge Coxe, we quote the following:

". . . Neither do we think that the testimony of learned experts and chemists, who have made many experiments to prove that the paint remover of the patent which does the work and satisfies the trade, is old and inefficient, can be relied on in the face of proof showing its widespread popularity and satisfactory results. Ellis was the first to produce such a remover. It is the hunter who actually brings down the game who is entitled to carry it home. The need

[1] See Metallurgical & Chemical Engineering, February, 1915, p. 129.

of an efficient and harmless paint remover had been felt for many years by the trade. Efforts to supply it were many but unsuccessful. Caustic alkali removers were tried and failed; they got rid of the paint but injured the wood. Carbolic-fusel oil removers were tried, but the carbolic acid proved dangerous to the workmen and injured the new paint when applied to the wood. All of these matters were considered in the litigation in the District Court and they were held not to negative the invention of the non-corrosive harmless removers of the Ellis patent.

"The Bennet and Arnstein removers were considered in the original case but were held not to defeat the invention of the Ellis patent and to belong to the same class as the other prior carbolic-fusel oil removers, where wax and similar substances were used as thickeners, and were not mentioned to retard evaporation. If the old removers were satisfactory and did the desired work why are they not used today? How can we account for this persistent effort, during ten years of litigation, to use the Ellis product, upon any other theory than that the prior removers were wholly insufficient? The necessity for a practical remover was felt and many experiments were tried, but no practical result was reached until the Ellis composition was produced.

"The testimony in support of this proposition is clear and persuasive; it is not necessary to review it in detail further than to say that it comes from manufacturers and large dealers and is to the effect that the carbolic acid-fusel oil removers were ineffective, dangerous to health, destructive to the wood, offensive in use and lamentable failures generally.

"The Ellis composition solved a problem which prior to 1902 had baffled the efforts of those who realized the dangers and shortcomings of the existing removers but seemed incapable of remedying them. The solution was not the result of a mere guess but was due to persistent effort by Ellis, who is an educated chemist of standing and reputation, who studied the problem with care and reached a solution which has solved the problem successfully. This is done without injuring the wood operated upon or endangering the health of the workmen. No one before had achieved this result.

"We see no ground for criticism of the patent *per se*. In fact we think the patentee and the officials of the Patent Office are to be commended for having issued a chemical patent where the description and claims cover less than a page. The patent is clear, concise and intelligible to laymen. The criticisms are not well founded. It was not necessary or wise to specify the exact proportion of wax, as this differs according to the work being done. Had the exact percentage been named, anyone could evade the patent by using more or less than the specified amount and thus could have secured all the advantages of the invention without the payment of a dollar."

International Engineering Congress

The International Engineering Congress will be held in San Francisco from September 20 to 25, 1915, under the auspices of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Institute of Mechanical Engineers, the American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers.

The membership fee is $5, and should be remitted to W. A. Cattell, treasurer, Foxcroft Building, San Francisco, Cal.

This membership fee entitles the member to

(a) Full participation in the Congress.

(b) A volume reporting the general proceedings of the Congress and containing indexes and digest of other volumes.

(c) Any single volume of the Transactions which the member may select.

There will be ten volumes, as follows: Vol. 1, The Panama Canal; Vol. 2, Waterways and Irrigation; Vol. 3, Municipal Engineering; Vol. 4, Railways and Railway Engineering; Vol. 5, Materials of Engineering Construction; Vol. 6, Mechanical Engineering; Vol. 7, Electrical and Mechanical Engineering; Vol. 8, Mining and Metallurgy; Vol. 9, Naval Architecture and Marine Engineering; Vol. 10, Military Engineering.

Pacific Coast Meetings of National Chemical Societies

All the three national chemical societies of this country will hold their autumn meetings in the West.

The start will be made by the **American Institute of Chemical Engineers**, which will hold a meeting in **Los Angeles, Cal.**, on the evening of Wednesday, **August 18th** (jointly with the Southern California Section of the American Chemical Society), and a four day meeting at **San Francisco** from **August 25th to 28th** (Wednesday to Saturday).

The next in time will be the **American Chemical Society**, which will hold its meeting in **Seattle**, Wash., from **August 31st to September 3rd** (Tuesday to Friday). On September 2 the party of the American Institute of Chemical Engineers will be in Seattle and attend the meeting of the American Chemical Society.

The **American Electrochemical Society** will hold its meeting in **San Francisco** on **September 16th, 17th, 18th** (Thursday to Saturday) simultaneously with meetings of the American Institute of Mining Engineers and the American Institute of Electrical Engineers. Joint sessions are planned. On Monday of the following week (September 20) the International Engineering Congress starts.

Exposition of Chemical Industries

A national exposition of chemical industries is proposed to be held in the New Grand Central Palace, Forty-sixth Street and Lexington Avenue, New York City, during the week of September 20 to 25, 1915.

While expositions of chemical industries have been held before in Europe, this will be the first chemical exhibition to be held in the United States.

The time for holding the exposition is undoubtedly well chosen. The psychological moment has come to place the achievements of industrial chemistry visibly before a wider and vitally interested public and to bring the manufacturers of machinery and apparatus for the chemical industries in such close contact with industrial chemists as the facilities of an exposition afford. If properly managed such an exposition must be of great benefit to the industry.

An advisory committee has been formed consisting of Messrs. Raymond F. Bacon, Charles H. Herty, A. D. Little, R. P. Perry, Wm. Cooper Procter, E. F. Roeber, George D. Rosengarten, T. B. Wagner and Utley Wedge.

The exposition is being organized and will be managed by Messrs. Charles F. Roth and Adriaan Nagelvoort, with offices at the New Grand Central Palace, Forty-sixth Street and Lexington Avenue, New York City (telephone Murray Hill 6990). Associated with them in the management is the International Exposition Company, which has successfully managed the Automobile Show, the Horticultural Show and others.

Beta Iron

"Satire Allotropique," presented at the dinner of the Iron and Steel Committee of the American Institute of Mining Engineers.

BY ALBERT SAUVEUR

Fer bêta, conception du grand allotropiste,
Contre toi, profitant de la sortie du maître,
Se rangent tes rivaux faciles à reconnaître,
Mirmidons entrainés par propos carbonistes.

Hadfield l'avait bien dit: le carbon seul durci.
Alpha, bêta, gamma, composants inutiles,
Ne pouvant arrêter le moindre projectile,
Doivent être relégués, et cela sans merci.

Arnold, chacun le sait, toujours a préféré,
Par lui seul découvert, un carbure éphémère,
Une formule étrange, véritable chimère,
Création fabuleuse qui ne peut qu'égarer.

Quant à Henry M. Howe, de nous tous le mentor,
Avec une justice qu'on rarement rencontre,
Il pèse sans faveurs les pours et les contres,
Et nous dira bientôt qui a raison ou tort.

Stead est décourageant par sa neutralité.
Tschernoff et Belaiew, fidèles amis slaves,
Des nouveautés anglaises ne seront pas esclaves,
Ce qui prouve après tout pour leur mentalité.

Guillet, Grenet, Charpy, Henri Le Chatelier
(Pour Frémont ces questions ont trop de théorique,
Son fort étant plutôt celui de la pratique)
Ne sont pas de bêta des ardents chevaliers.

Rosenhain avec lui semble jouer cache-cache:
Il l'attrape, il le tient, proclame qu'il est dur.
On accourt, on regarde, cette fois on est sûr,
Mais hélas aussitôt, voila qu'il le relâche.

C'est un slip band dit l'un, un simple glissement.
Du ciment dit un autre, un rien allotropique,
Pas même un métastable, un point mathématique,
Un décristallisé à chasser vitement.

Benedicks dans gamma le veut ensevelir,
McCance l'écrouir, Edwards en faire des mâcles:
Le malheureux bêta devant cette débâcle,
Se soumet à son sort, se résigne à mourir.

Il attend son destin, triste et mélancolique,
Abandonné de tous, même de martensite,
Qui prétend n'être plus que rides d'austénite.
Il deviendra amorphe. Adieu son point critique.

Pour comble de malheur, et sans le consulter,
Un docteur Suédois le veut mettre sous terre,
Assisté dans sa tâche, par Monsieur Carpenter,
Car, dit il, il est mort, on le peut constater.

Etant de phlogistique tellement dépourvu,
Qu'on ne sait en tirer le moindre point thermique,
Ni dans sa courbe voir la plus petite crique.
Tel manque de chaleur s'est très rarement vu.

Le verdict est rendu, le sort en est jeté:
D'un certain diagramme if faudra qu'on efface,
(Car on doit obéir à la règle des phases)
Ce déséquilibré, enfantement raté.

Quand vous aurez, Messieurs, fini vos beaux discours,
Et que l'heure viendra, pour gagner votre pain,
De durcir vos aciers et d'assurer vos gains,
Il faudra que bêta vienne à votre secours.

Obituary

Franklin Guiterman, director of the American Smelting & Refining Company, and manager of its Colorado department, died from pneumonia in New York City May 2. He was 59 years of age. Through his many years' experience in mining and smelting in the West, and his association with numerous companies for over 35 years, he was widely known as a competent metallurgist and business manager.

Mr. Guiterman was born in Cincinnati, O., where he received his early education. Later he attended Columbia University and finally graduated at the Bergakademie at Freiberg, Saxony, in 1877. Returning to the United States he became associated with some of his Freiberg classmates who were then engaged in the pioneer operations of mining and smelting in Colorado. Georgetown and Leadville, Colo., and Hartville, Wyo., were some of the scenes of his early work. Subsequently he went to Utah as superintendent of the Mingo plant of the Pennsylvania Lead Co. Returning to Denver in 1888 he entered the employ of W. J. Chamberlain & Co. as manager of the ore-buying business of that concern. In 1895 he was appointed manager of the Durango smelter in the San Juan district of Colorado. When the American Smelting & Refining Co. was formed he was made manager of its Pueblo plant and two years later he was made manager of the Colorado department of the same company, with headquarters at Denver. On March 1, 1912, he was transferred to New York, where he had charge of the research and technical investigations of the company and continued as manager for Colorado.

Mr. Guiterman was a prominent member of the Colorado Scientific Society, and as president of that organization for two years had much to do with its prosperity. He took an active interest in the affairs of national societies and belonged to the American Institute of Mining Engineers and the Mining & Metallurgical Society of America. In 1911 he was appointed a trustee of the Colorado School of Mines, but resigned when he removed to New York.

In 1886 Mr. Guiterman was married to Miss Mary B. Sproat, of Taunton, Mass. He is survived by his widow and one son, Kenneth S. Guiterman, chief chemist of the refinery of the Perth Amboy plant of the American Smelting & Refining Co.

Rewards for methods of utilizing alcohol for industrial and technical purposes have been offered by the Ministry of Finance, Russia, according to Consul General John H. Snodgrass, Moscow.

The premiums to be awarded are as follows:

(1) A premium of 100,000 rubles ($51,150) will be awarded for the invention of a new method of utilizing alcohol for the manufacture of a product that will be essentially different from the alcohol used for its production. Examples of such products are vinegar, ether, chloroform, etc.

(2) A premium of 75,000 rubles ($38,625) will be awarded for the invention of a new method of utilizing alcohol for the manufacture of a product in which alcohol and its derivatives (sulphuric ether and others) form the component parts of the product or the solvent, and from which it will be impossible to extract alcohol with a view to profit (as, for instance, pharmaceutical preparations).

(3) A premium of 50,000 rubles ($25,750) will be awarded for the invention of a method in which alcohol and its derivatives would serve as a temporary intermediary solvent (as in the manufacture of smokeless powder and artificial silk).

(4) A premium of 25,000 rubles ($12,875) will be awarded for the increase of the heating value of alcohol by the addition of substances that will make the use of alcohol as fuel advantageous.

(5) Three premiums of 5,000 rubles ($2,575) each will be awarded for the invention or improvement of apparatus for the utilization of spirits in internal-combustion engines and for heating and illuminating purposes.

Inventions must be presented by January 1, 1916. They must be presented to the Chief Administration of Taxes and Sale of Drinks, written in French or Russian, in special envelopes bearing some motto. In another envelope, bearing the same motto, must be stated the name and address of the sender.

The papers must contain a detailed description of the conditions of the adaptation of alcohol, indicating the cost of the method when calculating the price of alcohol at 2 kopecks (1 cent) per degree on the alcoholometer.

Premiums will be awarded only such inventions or improvements as will involve a considerable consumption of alcohol.

The Action of Certain Colloids on Ions During Electrolysis

BY A. MUTSCHELLER

Reports of investigations for the purpose of discovering suitable "addition agents" for electroplating and metal refining baths, are found to date back to as early as 1885 (M. Kiliani[1]). It had then already been recognized that the addition of certain substances to the bath had certain specific effects on the form and consistency of the deposit on the cathode. The nature of these investigations is purely qualitative, but more recently efforts have been made especially by Kern and his coworkers to find a theoretical explanation of the function of these "addition agents."

In reviewing the literature on this subject, especially the valuable articles of Kern,[2] certain analogies were found, as for instance, the general improvement of the deposit when the electrolyte is heated, or, that the quantity of an "addition agent" was found to be of importance, etc. These suggest that the additions must perform specific functions and that they do not act by their presence only. A selection from those substances which improve the deposit were recognized to be colloids and, as a rule, of the amphoteric or reversible type, hence colloidal phenomena were anticipated to be in play here. A further suggestion was found in the fact that the temperature coefficients on the rate of change of the migration velocity of the ions involved in the electrolysis are such that they tend to make the velocity of the two ions equal as the temperature rises. Moreover, the form of the deposit itself, such as it is obtained from a pure electrolyte in the form of striæ or branches was a sufficiently powerful inducement to a hypothesis that the regulation of the relative velocity of the ions should constitute the influencing factor in question. A few preliminary experiments substantiated this assumption and a more systematic continuation of these is herewith presented.

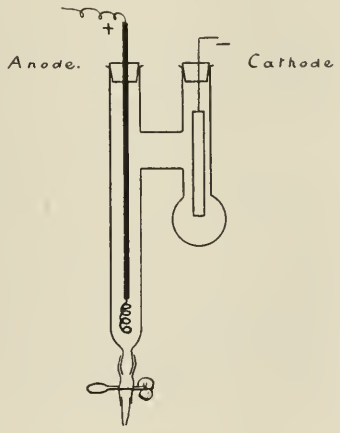


FIG. 1—HITTORF MIGRATION TUBE

EXPERIMENTAL PART ON SILVER NITRATE

The determination of the relative velocity of the ions was made in the customary manner by electrolyzing a salt solution in a so-called Hittorf's migration tube. This consists of an H-shaped tube about 1.5 cm in diameter of which one leg is about 15 cm long and closed by a rubber connection, a pinch cock and a glass tip. The other leg is short and closed at the bottom. The capacity of the tube is about 40 cc. (Fig. 1). For the determination, a foil of platinum about 6 cm^2 in area was placed in the shorter tube and made the cathode; in the longer leg was placed a glass tube through which a mercury connection was made and to the lower end of which was sealed a piece of the pure metal the migration velocity of whose ion was to be determined. This electrode was then connected with the positive pole of the electric current. The tube was filled near to the upper end with a solution which was prepared from c.p. chemicals and carefully distilled water. The current used was taken off along a resistance of about 36 ohms after it had passed from 2 to 6 incandescent lamps. The time of run was ordinarily from 1 to 1½ hours; care being taken in every case to prevent disturbance of the apparatus during the experiment.

The first series of experiments on silver nitrate, the results of which are given in Table 1, were performed in the above described tube and the determinations were made as follows:

After the electrodes (the anode in this case consisting of pure silver) had been put in place and the solution poured into the tube the apparatus was allowed to stand in a shady place for about 15 minutes. After everything had come to rest the circuit was closed.

In the meantime 5 weighing flasks were prepared and 5 cc. of a 1 10 normal NaCl solution and 2 drops of K_2CrO_4 solution were placed into each flask, after which the weight of each one was carefully determined.

After the run, the silver nitrate solution from the longer tube of the apparatus was run into the first weighing flask until the next drop produced a reddish precipitate or coloration. Then the other four flasks in turn were titrated in the same way, always employing care not to agitate the contents of the apparatus. After reweighing of each flask and deducing from the difference the known weight of $AgNO_3$ added (since the contents of the weighing flasks with respect to Cl' were of known titre, always the same weight of $AgNO_3$ was added to each flask), the remaining difference gave the weight of the water that contained the known amount of $AgNO_3$.

An increase of concentration of silver nitrate was thus easily found, and as a rule, the third weighing flask (and, of course, the fourth and fifth) contained the same and constant amount of $AgNO_3$.

The use of diaphragms, therefore, did not appear to be necessary so long as there was an increase of silver at the silver anode in the long leg of the tube. When the contrary was observed the arrangement of the electrodes was reversed so that it never happened that a solution of higher density was placed above one of lesser density. Vitiation of results due to diffusion seemed, therefore, satisfactorily prevented.

From the results obtained in this way the ionic migration velocities were calculated in accordance with the principle developed by Hittorf.[3] Calling c the amount of silver deposited on the cathode, r the amount of NO_3 (all expressed as $AgNO_3$) and n the migration velocity of the anions we have

$$c:r::1:n$$

and 1-n as the migration velocity of the cations.

In this series of experiments the concentration of the electrolyte consisting of a normal solution of silver nitrate was kept constant for all determinations, except that for each run a varying addition of a 1 per cent solution of gelatine was made. The results of these additions on the migration velocities of the ions are given in Table 1 and are plotted in curve No. 1.

The ordinates represent the relative migration velocity of the NO_3- when varying additions of gelatine solution (1 per cent) have been made, as correspondingly represented as abscissæ.

A pure white and well adhering deposit of silver was obtained when the migration velocity of the NO_3 is near zero. Before that, so long as there was less gelatine added than was necessary to bring about this condition, the deposit was loose, brittle and in the form of trees and striæ. It was also distinctly noted that gelatine gathered around the anode in the form of a slimy, gelatinous layer. When more gelatine was added the deposit on the cathode was gray and black, but firmly adherent. The deposit was washed with water, alcohol

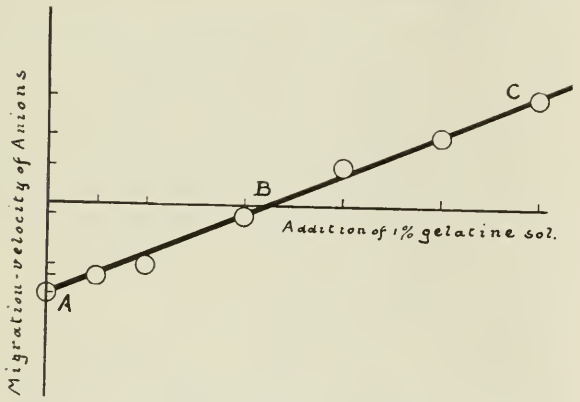
1. Berg und Hüttenwesen Zeitschr., p. 249 (1885).
2. Trans. Am. El. Chem. Soc., 15, 441 (1909).
3. Ostwald's Klassiker No. 23, § 4.

and ether, very slightly warmed and after cooling in a dissicator weighed as such. Subsequent heating when the addition of gelatine was more than 2 cc, changed its color which was evidently due to the burning off of organic matter which had deposited along with the silver.

A second series of experiments was performed in exactly the same way and under the same precautions, but varying the conditions in the way of keeping the gelatine addition constant, but varying the concentration of

TABLE I

Experiment No.	Silver Deposited on Cathode Expressed as Ag	Ag NO_3	NO_3 Migrated Expressed as Ag NO_3	Toward	1% Gelatine Solution Added to 40 c.c. of Electrolyte	Concentration of Electrolyte	n(=Migration Ratio of N_3 Calc. from Data)	Form and Quality of Deposited Silver on Cathode
1	0.1505	0.2375	0.1360	Anode	No addition	Normal	0.562	Non-adherent forming trees.
2	0.1130	0.1600	0.0865	Anode	No addition	Normal	0.542	The same.
3	0.058	0.092	0.039	Anode	.5 c.c.	Normal	0.445	Vertical striae, badly adherent.
4	0.095	0.151	0.056	Anode	1. c.c.	Normal	0.370	Vertical striae, better adherent.
5	0.178	0.282	0.015	Anode	2 c.c.	Normal	0.053	Pure white, well adherent, smooth.
6	0.114	0.181	0.0425	Cathode	3 c.c.	Normal	−0.235	Smooth, well adherent, slightly gray.
7	0.122	0.194	0.082	Cathode	4 c.c.	Normal	−0.425	The same. Dark
8	0.142	0.224	0.149	Cathode	5 c.c.	Normal	−0.665	gray to black.



CURVE 1—CURVE OF MIGRATION VELOCITIES

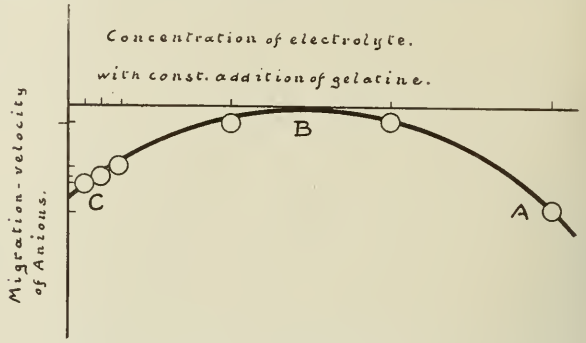
the electrolyte. As constant addition of gelatine was kept that quantity which, with a normal silver solution reduces the migration velocity of the NO_3^- to zero. Varying then the concentration of the electrolyte with this constant addition of 1 per cent gelatine solution from 1/10 normal to 3 normal, the results given in Table 2 were obtained. The analytical methods and

TABLE II

Experiment No.	Silver Deposited on Cathode Expressed as Ag	Ag NO_3	NO_3 Migrated Expressed as Ag NO_3	Toward	1% Gelatine Solution Added to 40 c.c. of Electrolyte	Concentration of Electrolyte	n(=Migration Ratio of NO_3 Calc. from Data)	Form and Quality of Deposited Silver on Cathode
1	0.070	0.1105	0.084	Anode	2 c.c.	N/10	0.240	Gray, well adherent.
2	0.067	0.1057	0.0818	Anode	2 c.c.	N/5	0.220	Same Form
3	0.099	0.156	0.1262	Anode	2 c.c.	N/3.3	0.19	Smooth, slightly gray.
4	0.178	0.282	0.015	Anode	2 c.c.	N	0.053	Pure white, well
5	0.260	0.409	0.389	Anode	2 c.c.	2 N	0.05	adherent.
6	0.222	0.351	0.236	Anode	2 c.c.	3 N	0.328	Striae, not well adherent.

methods of procedure were exactly identical with those for the first series.

The form of the deposit along part *CB* of Curve 2 is gray and black, gelatine having deposited. At point B the deposited silver is pure and stronger heating of the platinum cathode did not cause any loss of weight. Considerable loss was observed on heating the same in the case when lower concentrations of $AgNO_3$ solution



CURVE 2—CURVE OF MIGRATION VELOCITIES

were employed (part *BC* of the curve). Along part *BA* the deposit was pure but with a tendency to form striæ and loose deposit.

EXPERIMENTS WITH COPPER SULPHATE

Valuable information was expected to be obtained by studying the effect of adding gelatine solution to an electrolyte consisting of bivalent ions; copper sulphate was chosen for this purpose. A further point kept in view was to determine the change of concentration around both electrodes. This, however, cannot be done satisfactorily in the usually employed Hittorf tube above described, and a special tube was constructed to meet with the above requirements. Its diagram is given in

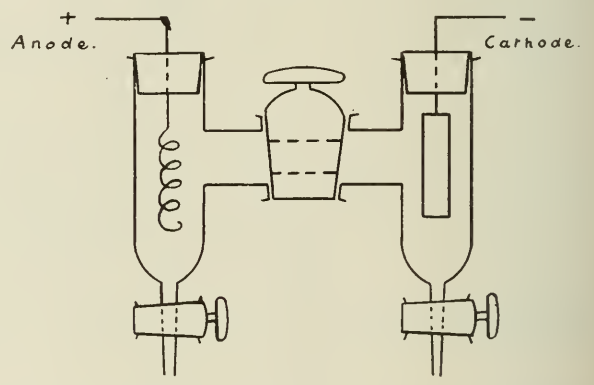


FIG. 2—TUBE FOR DETERMINATION OF CONCENTRATION

Fig. 2 and in use it was found to answer the purpose very satisfactorily.

It consists of two separate compartments for the electrodes, each one provided with an outflow closed by a glass stopper. These two compartments are connected by a side branch connection in the middle of which there is a large glass stop cock. The purpose of this middle large-hole glass stop cock is that by closing the same after the experiment all diffusion can be prevented.

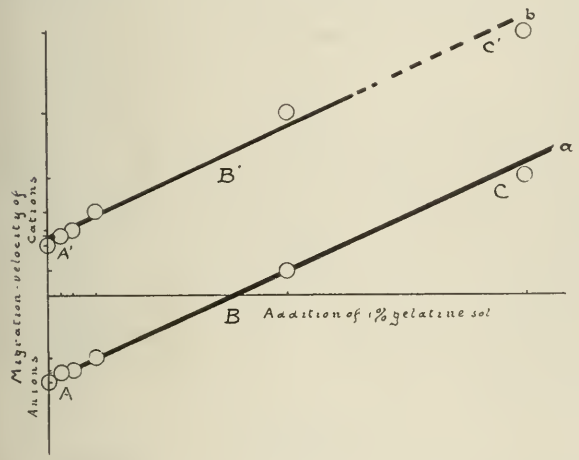
During the experiment the stop cock was kept open and it is, of course, necessary to prevent agitation or disturbance of the apparatus. After the experiment and turning off of this stop cock the electrodes are removed and so the possibility of local action due to stay of the electrodes in the solutions is excluded. Once these precautions have been applied, the contents of the vessels can then be analyzed at leisure. The capacity of this apparatus with the electrodes in position is about 45 cc.

For this third series the technic of analysis was

altered and titration of the copper by KCN solution was found to give satisfactory results. The solution of one compartment was run into an accurate burette for the purpose of determining its volume. From this burette an aliquot volume was run into a beaker, NH_4OH was added until the maximum of blue color was reached and the volumetric KCN solution was run in until the last drop caused the disappearance of the blue color. From this the concentration of the $CuSO_4$ was calculated and by comparing this with a blank determination before the electrolysis the change of concentration was calculated.

In weighing of the platinum foil which had served as cathode the same method was followed which is washing with distilled water, alcohol, and ether, very slight warming, cooling in the dissicator and rapid weighing. Hence, in this case also, all organic matter which had deposited along with the copper when the large additions of gelatine were made was weighed and expressed as copper. However, we are now to recall that, when smaller additions of gelatine were made the gelatine gathered around the anode, whereas the cathode remained pure and did not lose any weight on heating. Only then, when larger additions of gelatine were made did stronger heating cause a loss in weight of the cathode. This is also the result of the first series; when there is an excess of gelatine it deposits on the cathode as a black layer.

For this reason the first part of Curve 3 (from *A* to



CURVE 3—CURVES OF MIGRATION VELOCITIES

B) includes pure deposits of copper and hence represents true migration velocities; from *B* on, however, the part representing the relative velocity of Cu^{++} larger than 1, is not a representation of real migration velocities. Moreover, this illustrates that gelatine takes part in the electrolysis in accordance with its electric charge.

The results obtained in this series are given in Table 3 and are also represented in Curve 3. Comparing the numerical results and inspection of the curves show that they run parallel.

DISCUSSION

These experiments lead to the general result that, if to a given concentration of an electrolyte gelatine solution is added in a small quantity, the velocity of migration of the anions is decreased and gelatine, together with the absorbed anions, migrate to the anode. On increasing this addition a point is reached where this gelatine-anion complex ceases to migrate while the relative migration velocity of the cations has become equal to 1. If, finally, this addition is further increased it is found that the complex gathers on the other electrode, the cathode, where it deposits with the metal.

Furthermore, it follows from these data that the

TABLE III

Experiment No.	Copper Deposited on Cathode Expressed as		SO_4 Migrated		Cu^{++} Migrated		Gelatine Added to 40 c.c. of Electrolyte	Concentration of Electrolyte	n(=Migration Ratio of $\frac{1}{2}SO_4^=$)=Calculated from Data	$1-n$(=Migration Ratio of $\frac{1}{2}Cu^{++}$)=Calculated from Data
	Cu	$CuSO_4$	Expressed as $CuSO_4$	Toward	Expressed as $CuSO_4$	Toward				
1	0.038	0.079	0.0514	Anode	0.0304	Cathode	No addition	Normal	0.650	0.380
2	0.067	0.1396	0.0792	Anode	0.0626	Cathode	4 c.c.	N.	0.567	0.448
3	0.075	0.1563	0.0882	Anode	0.0774	Cathode	10 c.c.	N.	0.564	0.495
4	0.042	0.0875	0.0418	Anode	0.0541	Cathode	20 c.c.	N.	0.477	0.617
5	0.067	0.1396	0.0271	Cathode	0.194	Cathode	100 c.c.	*N.	−0.194	1.389
6	0.039	0.0813	0.096	Cathode	0.1660	Cathode	200 c.c.	N.	−0.896	2.042

Form and quality of deposit: Streaky, not well adherent in 1, 2, 3, 4
Smooth and pure in 5, 6

*(In Table 3.) In some of the experiments for curve 3 it has been necessary to add for example 100 or 200 cc. of a 1 per cent solution of gelatine to 40 cc. of electrolyte, which would amount to a considerable further dilution. For this reason a stronger solution was added but represented in terms of a 1 per cent solution. This might slightly influence the numerical results, for, gelatine solutions at different dilutions exhibit different colloidal properties; considering, however, the remarks on this part of the curve, the differences become negligible.

$\frac{1}{2}(SO_4^=)$ requires an addition of gelatine solution which is about 45 times that which is required to cause the same effect on the NO_3^-. This ratio can be read off directly from the curve, thus for example, the distance from the ordinate axis to the intersection of Curve 1 is to the same distance of Curve 3 as 1 is to 45.

The phenomenon here observed is not a chemical reaction between the electrolyte or one of its ions and gelatine nor a mechanical mixture, but has all the characteristics of a process called absorption. J. M. van Bemmelen[4] and H. Freundlich show that absorption phenomena between colloidal gels and dissociated crystalloid solutions are phenomena of very frequent occurrence. They also show that, especially if the absorbing substance is an emulsoid, the crystalloid very often is split in parts of which but one is absorbed. J. M. van Bemmelen[5] has compared the absorption phenomena with the distribution of a solute between two immiscible solvents, whereby $\frac{C_1}{C_2} = f(k)$, thus k in the case of a process of absorption is a function depending on a number of factors and not a constant as it is in the case of a solution.

The investigations of H. Freundlich[6] on the absorption of the liquid by the solid phase led to the formula

$$\frac{x}{m} = ac^{\frac{1}{q}}$$

which formula has been applied and is considered as typically representing the process of absorption. The exponent varies little, between 0.5 and 0.8.

The coefficient a, however, while constant for one and the same substance differs widely, especially with the chemical nature of the absorbing substances. W. M. Bayliss[7] found that its value changes decreasingly with the anion branch of the Hofmeister series.[8] Again H. Freundlich[9] shows that the precipitating power of monovalent ions on positively charged colloidal $Fe(OH)_3$ is to that of divalent ions as 1 is to 40 or 50, or about 45. It is also shown that the cations have an influence on this ratio, so that this result is in fair agreement with the results obtained. Whetham,[10] working on the scale of approximation, found this ratio of the power of precipitation of monovalent and divalent ions as 1 is to 40 ($M':M'':M''' :: 1:40:1600$).

4. Zeitschr. f. phys. Chem. 45, 307 (1903).
5. Zeitschr. f. anorg. Chem. 23, 111, 321 (1900).
6. Zeitschr. f. phys. Chem. 57, 385 (1907).
7. Biochem. Journ. 1, 175 (1906).
8. Arch. f. exp. Path. & Pharmokol., 28, 210 (1891).
9. Zeitschr. f. phys. Chem. 73, 387 (1910).
10. Journ. of Physiol., 24, 301 (1899).

The observed effects resulting from the addition of gelatine to electrolytes, therefore, are the same as those that characterize typical absorption phenomena; hence, we may conclude that gelatine absorbs selectively the anions of the electrolyte and that whichever is present in greater quantities, the anions or the colloid, determines the character, such as the electric charge, etc., of the absorption complex.

The investigations of S. E. Linder and H. Picton[11] cleared the nature of migration of colloids under the influence of the potential gradient (cataphoresis). W. B. Hardy[12] observed that the addition of an alkali to a solution of albumin caused the same to migrate to the anode, whereas addition of acid reversed the direction of their migration. Moreover, Wo. Pauli[13] confirmed these results and found that a carefully dialyzed albumin solution did not show any migration of the albumin.

We must, therefore, assume as probable that the colloidal gelatine carried a positive charge of electricity and when absorbing the anions either partly or fully or overneutralized their electric charge, according to the relative amount of colloid present compared with the anions. Evidently at the point where the migration velocity curves of the anions cross the axis of abscissae, the charge of the anions was just balanced by the charge on the colloid, for as reported in this case the colloid and the anions ceased to migrate in either direction.

The nature of the observed phenomenon, therefore, being that of an absorption process we might with J. Duclaux[14] and Malfitano look upon the electrical charge of a colloid as an absorption potential, and if we continue this analogy we would have to look upon a colloidal particle as a complex ion and a combination of an ionized salt with a colloid in a solution as a highly complex electrolyte.

Electrically neutral particles, neutrions or isocolloids are known not to migrate under the influence of the potential gradient. The anions and the colloid having entered into such a neutral union, which at the same time is hardly at all ionized itself are, therefore, rendered unsusceptible to the influence of the electric field, which, it is to say, is at the point where the velocity of the anions has been reduced to zero.

Calling now the mobility of the anions and the cations l_a and l_k respectively and E the current which passes through the cell, then $\frac{l_a}{l_a + l_k} E$ of it is carried to the anode by the anions and $E \frac{l_k}{l_a + l_k}$ to the cathode by the cations, hence

$$E \frac{l_a}{l_a + l_k} + E \frac{l_k}{l_a + l_k} = E. \qquad (1)$$

From this expression follows, that whatever velocity is lost by one ion is correspondingly gained by the other and that the curves representing the relative velocities of the ions must run parallel. This is realized experimentally in Curve 3.

Again, finding experimentally that the addition of gelatine to the electrolyte causes the velocity of the anions to decrease to zero it follows that,

$$E \frac{l_a}{l_a + l_k} = 0 \qquad (2)$$

Introducing this in (1) we obtain

$$E \frac{l_k}{l_a + l_k} = E \qquad (3)$$

Thus, the cations carry the whole charge of the current and consequently must migrate as fast as they deposit. The concentration of the cations around the cathode must, therefore, remain unchanged.

From these experiments it is evident that there exists a deposition optimum at the point where the negative charge of the anions is exactly neutralized by the colloid. The isocolloid formed is known not to migrate and so, through continued electrolysis we would obtain an accumulation of isocolloid in the electrolyte. At the anode, therefore, we should not have the regular secundary reaction taking place, which otherwise is,

$Ag^+ + NO_3^- = AgNO_3^\circ$ (and $AgNO_3^\circ = Ag^+ + NO_3^-$ etc.)

Instead, however, the following reaction takes place:

(1) $Ag^+ + HNO_3^\circ = AgNO_3^\circ + H^+$.

The hydrogen ion formed in turn reacts on the colloid and isocolloid in accordance with the following reaction:

(2) $H^+ + gelat.NO_3^\circ = HNO_3^\circ + gelat.^+$; thus rendering the gelatine once more available to perform its function.

But, in order to liberate all of the bound gelatine, the isocolloid must be brought near to the anode by stirring and it appears as if the force of the electric field to which the electrically neutral particle is unsusceptible must be supplied by mechanical power from a stirring apparatus. In accordance with the above equations, there would be no expenditure in acid nor any of gelatine.

It must be considered, however, that gelatine is a highly complex molecule which, under the strain of the various chemical and electrical treatments would be expected to break down into its component parts. In this sense, then, will there be a slight expenditure of gelatine.[16]

The expenditure of gelatine is considerably greater if the electrical charge of the anions is overbalanced by an excess of gelatine in the acid solution. The particles formed migrate to the cathode and deposit there as the observed black or gray deposit of gelatine. Conversely, if not enough gelatine was added to the bath the gelatine migrates to the anode where it is separated from the acid radicle and forming the observed slimy layer on the anode. Both of these deposits are irreversible and constitute a loss probably in both gelatine and acid.

CONCLUSION

The conclusions derived from the foregoing experimental data are:

First.—Colloidal gelatine in an acid electrolyte forms an absorption compound with the anions, thereby either partly or totally neutralizing or reversing their initial charge according to the quantity of gelatine added.

Second.—The gelatine is combined with the anions in such a way that in one case (part A-B of the curve) their velocity of migration is greatly reduced. In another case (point B) their velocity is zero, and in the third case (part B-C of the curve) the direction of their migration is reversed, i.e., the anions migrate to the cathode instead of to the anode.

Third.—Through the decrease of the velocity of the anions the cations gain in velocity proportionally, so that at the point where the anion-migration-velocity is equal to zero the cations carry the full quantity of electricity across the electrolyte. In this way the cations migrate to the cathode as fast as they deposit, and experiments show that at that point only, where the relative migration velocity of the cations is near 1, the metallic deposit on the cathode is smoothest and purest.

This property of gelatine is evidently analogous to

11. Journ. Chem. Soc. 61, 148 (1892).
12. Journ. of Physiol., 24, 288 (1899).
13. Beitr. z. chem. Phys. und Path., 7, 531 (1906).
14. Kolloid Zeitschrift, 7, 73 (1910).
15. Zeitschr. f. Phys. Chem., 68, 232 (1909).

16. This "breaking down" of gelatine has led a number of investigators to believe in a reducing effect of the gelatine when added to the electrolyte.

the property of certain colloids, which property Zsigmondy[17] designated as their "protective action" or "Schutzwirkung," a property which he has measured quantitatively by the action of such colloids on a colloidal gold solution of an intensely red color. The quantity of colloid necessary to prevent the change of color of 10 c.c. of this red gold solution, which contains a known quantity of gold, over into blue after the addition of 1 c.c. NaCl solution he expressed as the "Goldzahl" or gold number of the colloid. The reciprocal of this "Goldzahl" then expresses the protective action of the colloid upon colloidal gold, which, as we know, also carries a negative charge.

Among a series of colloids gelatine has the value of approximately 200. Gum arabic has the value of about 5; whereas soluble starch has the value of about 0.04. Using these last two colloids instead of gelatine, it was found that their action of neutralizing the charge of anions is proportional to the reciprocals of these ratios.

Chemical Laboratory, Pathol. Dept., German Hospital and Dispensary, New York City.

Comparative Furnace Efficiency

BY R. J. WEITLANER

When dealing with heating or melting furnaces in the iron and steel industry the words "efficiency" and "economy" are often used and are still more often confused with one another. It seems therefore pertinent to define these expressions more carefully. We should, for instance, distinguish between "pyrometric" and "thermic" efficiency of a furnace. "Pyrometric efficiency" I call the ratio of heat in metal to the heat in fuel used, or in other words: the ratio of the heat utilized in metal to the heating power of the fuel consumed during this process. This pyrometric efficiency is usually in our mind when we speak of furnace efficiency.

"Thermic" efficiency or "effect" of a flame or a fuel I call the ability of a fuel to develop more or less heat-units in a given space at a time. This is usually expressed as the "intensity" of the flame. If the heat exchange between flame and metal is purely by radiation and not by conduction it is, according to Stefan, proportional to the difference of the fourth powers of their respective absolute temperatures; therefore higher "thermic efficiency" is mostly the cause of a higher "pyrometric efficiency."

Thirdly, if we consider the lower or higher cost of heating or melting we arrive at a third conception, that of "economy." This treats the value of fuels and furnaces from a mere financial standpoint and takes into consideration cost of fuel, labor, maintenance, power, investment and it may be that the latter items (labor, maintenance, etc.) exceed the fuel cost (water-gas).

A few examples may serve to illustrate the practical meaning of these definitions.

17. "Kolloidchemie."

Taking, for instance, an ordinary coal-fired heating furnace for billets at a temperature of about 2200 deg. Fahr., we may have an average coal consumption of 450 lb. of coal per ton (2000 lb.) of metal heated. We find the "pyrometric furnace efficiency" from the formula:

$$E = \frac{2000 \text{ lb.} \times 360 \text{ B.t.u.} \times 100 \text{ per cent}}{450 \text{ lb.} \times 14{,}000 \text{ B.t.u.}}$$

wherein 360 B.t.u. represents the heat-content of 1 lb. of steel at 2200 deg. Fahr., and 14,000 B.t.u. the heat value of 1 lb. of coal. This gives the "pyrometric efficiency"

$$E = 11 \text{ per cent.}$$

The "thermic efficiency" of such a coal-fired furnace as represented by the obtainable flame temperature will be somewhat limited on account of incomplete combustion, excess of air, etc.

If we now replace for this same furnace the method of direct coal firing by the use of powdered coal, we may be able to reduce the coal consumption to 300 lb. of coal per ton of metal. This gives a "pyrometric efficiency" of approximately 17 per cent. This increase in efficiency for the same furnace with the same fuel was only possible through an almost theoretical combustion of the powdered coal and a subsequent higher flame-temperature or thermic effect.

If the cost for pulverizing 1 gross ton of coal amounts to about $1 and the gross ton of coal costs $3, we obtain the cost for heating 1 ton of steel as follows:

$$\text{For direct firing } \frac{300 \times 450}{2240} = 60.3 \text{ cents.}$$

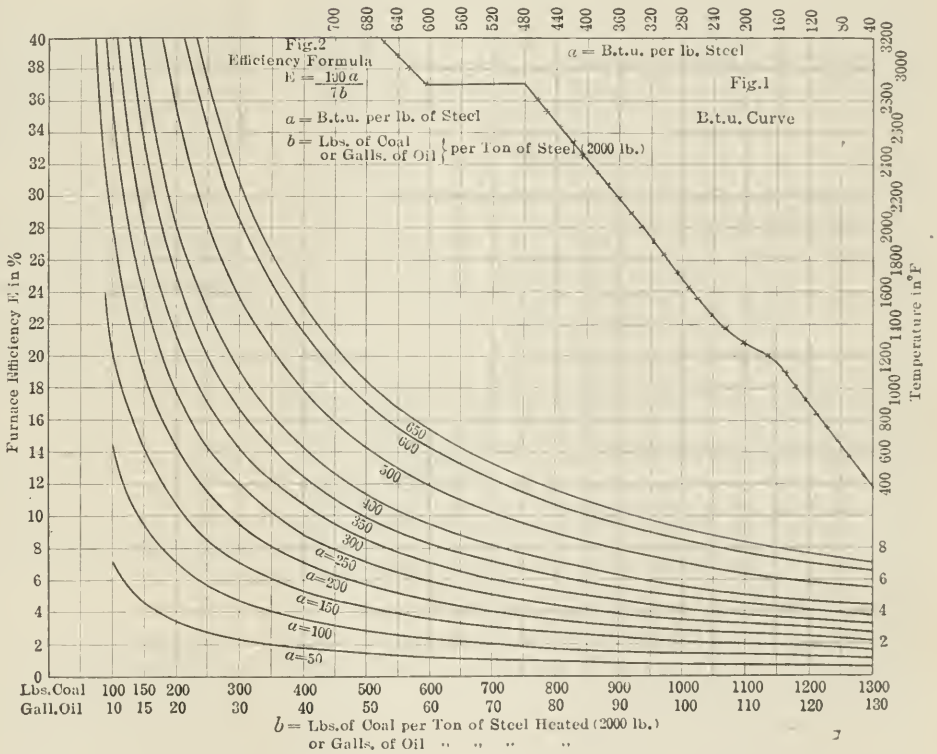


Fig.2
Efficiency Formula
E = 130a / 7b
a = B.t.u. per lb. of Steel
b = Lbs. of Coal or Galls. of Oil per Ton of Steel (2000 lb.)
a = B.t.u. per lb. Steel
Fig.1
B.t.u. Curve
Furnace Efficiency E in %
Temperature in °F
650
600
500
400
350
300
a=250
a=200
a=150
a=100
a=50
Lbs.Coal 100 150 200 300 400 500 600 700 800 900 1000 1100 1200 1300
Gall.Oil 10 15 20 30 40 50 60 70 80 90 100 110 120 130
b = Lbs.of Coal per Ton of Steel Heated (2000 lb.)
or Galls. of Oil " " " "

FIG. 1—B.T.U. CURVE. FIG. 2—EFFICIENCY CURVES

$$\text{For powdered-coal firing } \frac{400 \times 300}{2240} = 53.6 \text{ cents.}$$

We see that in this specific case we obtain not only a superior thermic and pyrometric efficiency by the use of powdered coal, but also a higher economy.

Let us further assume that for some reason this furnace should be changed to fuel oil. We know that on account of the concentrated form of this fuel the thermic and pyrometric efficiency will be higher than when ordinary coal firing is used. Here, however, the price

Table I.—Heat-Content in Iron (J. W. Richards)

Temperature °C.	Temperature °F.	Heat-Content Cal. p. Kg.	Heat-Content B.T.U. p. lb.
250	482	30.5	54.9
300	572	37.7	67.88
350	662	45.0	81.8
400	752	52.2	93.96
450	842	60.3	108.54
500	932	68.3	122.94
550	1022	76.7	138.06
600	1112	85.0	153.0
650	1202	95.1	171.18
700	1292	111.8	201.24
750	1382	125.6	226.08
800	1472	135.8	244.44
850	1562	144.4	259.92
900	1652	152.8	275.04
950	1742	160.4	288.72
1000	1832	167.8	302.04
1050	1922	175.4	315.72
1100	2012	183.0	329.4
1150	2102	191.7	345.06
1200	2192	200.0	360.
1250	2282	208.3	374.94
1300	2372	216.1	388.98
1350	2462	224.2	403.56
1400	2552	233.1	419.58
1450	2642	241.4	434.52
1500	2732	250.0	450.
1550	2822	258.3	464.94
1600 solid	2912	266.7	480.06
1600 liquid	2912	336.0	604.8
1650	3002	346.0	622.8
1700	3092	356.0	640.8
1750	3182	366.0	658.8
1800	3272	376.0	676.8
1850	3362	386.0	694.8

of fuel oil will set a limit to its ability to compete commercially with coal.

Basing the substitution of coal by oil on their respective heat values, we would have 1 gal. of oil equivalent to 10 lb. of coal. But on account of the higher "thermic effect" we assume that 1 gal. of oil is equivalent to 13 lb. of coal. For the oil equivalent to 450 lb. of coal required per ton of steel we therefore get

$$450 \div 13 = 34.6 \text{ gal.}$$

60.3 cents $\div$ 34.6 = 1.74 cents is the price we can afford to pay for 1 gal. of fuel oil, provided no other reasons speak for the use of this fuel.

We may consider it a safe rule to assume that the higher the temperature to which the metal is to be heated the higher the "thermic effect" of the flame must be to insure a fair "pyrometric efficiency" of a furnace.

Through selection of the fuel or of the furnace system we have it to a great extent in our hand to obtain the desired result. This is quite plainly illustrated in an electric furnace. While the electric furnace has the highest pyrometric efficiency of any metallurgical furnace, yet it is more economical to melt the cold charge in an open-hearth furnace and to treat the molten steel afterward in an electric furnace, in which we are able to obtain a wide temperature difference between the molten metal and the electric arc, this fact being so essential for a high pyrometric efficiency.

The writer of this article has tried to bring all the different fuels and systems of firing into certain relations with each other and to develop simple formulas by the use of which we should be able to calculate and compare efficiencies and economies of all kinds of fuels and furnaces.

It must be understood, however, that all the following figures were calculated for special assumed cases and that they are therefore subject to modifications in each particular case, as to the heating value of fuels, cost, etc., and will have to be worked out separately for each locality or plant.

The principle upon which all the calculations and formulas are based is the heat content of the material which was heated or melted.

This heat content as given in Table I is taken from J. W. Richards' "Metallurgical Calculations," page 201, and gives the heat in iron in calories per kilogram, or in British thermal units per pound at different temperatures. In Fig. 1 a curve is given for the British thermal units per pound of steel as function of the temperature in degrees *F*. For convenience we call this value *a*. Let us further designate with *b* the amount of fuel used in any furnace to bring 1 ton (2000 lb.) of metal up to the temperature for which the heat content was *a*.

From these two items the efficiency and cost formulas for different fuels shall be derived.

Coal

According to our definition given before the efficiency of a furnace in per cent is the ratio

$$\frac{\text{heat in metal} \times 100}{\text{heat in coal used}}$$

Assuming an average heat value per pound of coal of 14,000 B.t.u. we have

$$E_{coal} = \frac{a \times 2000 \times 100}{b\,(\text{in pounds}) \times 14{,}000 \text{ B.t.u.}} = \frac{100a}{7b}$$

This simple formula will be of use in most cases where the heat value of coal is not far from the one assumed.

Table II.—Efficiencies. With Varying "a" and "b"

a	°F. Approx.	b=Lbs. of Coal per Ton of Steel (a 2000 Lbs.) 100	150	200	300	400	500	600	800	1000	1306
50	445	7.143	4.760	3.572	2.380	1.795	1.428	1.190	.893	714	.549
100	806	14.286	9.520	7.143	4.760	3.590	2.857	2.381	1.786	1.429	1.099
150	1094	21.429	14.280	10.714	7.140	5.385	4.285	3.571	2.679	2.143	1.648
200	1292	28.570	19.050	14.286	9.570	7.140	5.712	4.760	3.570	2.856	2.198
250	1508	35.713	23.810	17.857	11.950	8.935	7.140	5.950	4.463	3.570	2.747
300	1820	42.856	28.570	21.429	14.330	10.730	8.569	7.141	5.356	4.285	3.297
350	2170	50.000	33.333	25.000	16.710	12.525	9.997	8.331	6.249	4.999	3.846
400	2444		38.100	28.572	19.140	14.280	11.424	9.520	7.140	5.712	4.396
500			47.60	35.715	23.800	17.950	14.285	11.905	8.930	7.145	5.495
600	2912			42.858	28.560	21.540	17.142	14.286	10.716	8.574	6.594
650	3130				30.94	23.335	18.570	15.476	11.609	9.288	7.143

In Table II the values of *E* are given for varying *a* and *b* and the results are plotted graphically in Fig. 2.

To arrive at an example for cost formulas we assume that 1 gross ton of coal costs $3 and that 50 cents is the expense of handling it, so that the total cost of 2240 lb. of coal is $3.50, hence that of 1 lb. 0.1563 cent.

The cost for heating 1 ton (2000 lb.) of steel will be $C = b \times 0.1563$ cent. From the efficiency formula we obtain $b = \frac{100a}{7E}$ and the cost formula is

$$C = \frac{100a \times 0.1563}{7E} = \frac{15.63a}{7E} = \frac{2.232a}{E}$$

This, of course, holds good only for the above assumptions.

Producer Gas

Using producer gas as a fuel the combined efficiency of producer and furnace will remain the same, only the cost of preparation will be higher. We assume a cost of $3.50 for 1 gross ton of gas coal and an additional cost of $1.25, or a total cost of $4.75 per gross ton, or 0.212 cent per pound of coal.

$$E_{coal} = \frac{100a}{7b}$$

(b = pounds of coal gasified per ton of steel.)

$$\text{Cost } C = b \times 0.212 = \frac{21.2a}{7E} = \frac{3.03a}{E}$$

Powdered Coal

Again we have

$$E_{coal} = \frac{100a}{7b}$$

Let us further assume the cost of 1 gross ton of gas slack to be $2.50, and the cost of pulverizing $1.25, so that the cost of 1 gross ton of powdered coal is $3.75, or 0.1674 cent the cost per pound.

$$\text{Cost } C = b \times 0.1674 = \frac{16.74a}{7E} = \frac{2.391a}{E}$$

Oil

Turning to oil we can establish similar formulas by taking b in gallons per ton of steel heated and assuming an average heat-value of 140,000 B.t.u. per gallon of fuel oil:

$$\text{Efficiency: } E_{oil} = \frac{a \times 2000 \times 100}{b \times 140{,}000} = \frac{10a}{7b}$$

In order to obtain the cost formula we assume the cost of 1 gal. to be 2.45 cents and the cost of handling 0.55 cent, hence total cost per gallon is 3 cents.

Cost of heating 1 ton of steel:

$$C = 3b$$

$$b = \frac{10a}{7E}$$

$$C = \frac{30a}{7E} = \frac{4.3a}{E}$$

With varying oil prices we get, for instance,

4 cents per gal. + 0.5 cent for handling Cost $C = \frac{6.43a}{E}$

6 cents per gal. + 0.5 cent for handling Cost $C = \frac{9.3a}{E}$

Wood Fired Furnaces

Although of relative low and greatly variable heating value, wood is still sometimes used for moderate temperatures, for instance, in annealing furnaces.

One cord of pine wood weighs about 2000 lb.

One pound of pine wood with 25 per cent H_2O (air dried) develops approximately 6000 B.t.u.

$$E_w = \frac{a \times 2000 \times 100}{b \times 6000} = \frac{100a}{3b}$$

b = pounds of wood per ton of steel.

We may assume the cost for one cord of pine wood to be $4, including handling.

1 lb. dry wood = 0.2 cent

$$\text{Cost } C = \frac{100a \times 0.2}{3E} = \frac{6.67a}{E}$$

Electric Power

Derived similarly, we obtain from

1 kw = 3412 B.t.u.

b = kilowatt-hours per ton of steel heated or melted

$$E = \frac{a \times 2000 \times 100}{b \times 3412} = \frac{58.617a}{b}$$

with varying prices of 1 kw-hr.:

1 kw-hr. 1 cent: $\frac{58.617a}{E}$

1 kw-hr. 1.25 cents: $\frac{73.27a}{E}$

1 kw-hr. 1.5 cents: $\frac{87.926a}{E}$

After having established these formulas it should be understood that said efficiencies are based only on such a fuel consumption which was necessary to bring the material up to the desired temperature to melt or to perform a certain metallurgical process. This efficiency is termed by Prof. J. W. Richards the "specific efficiency."* From this we have to distinguish such fuel consumption as is necessary to keep or "hold" the material at that temperature.

Such cases, for instance, occur mostly in annealing furnaces where the steel, after having been brought up to the desired heat, is kept for a certain period at that temperature. This is called by Professor Richards "generic efficiency" or "holding efficiency" as we may also term it. Even under similar conditions of temperature and "holding time" the fuel consumption b has to be given in pounds, gallons, kilowatt-hours per hour† and the cost will be figured directly from this fuel.

The fuel consumption per hour in each furnace will, of course, be a function of the temperature at which the furnace is held.

For the sake of comparison, a number of cost formulas were worked out for various fuels, prices of fuel and handling cost and arranged in Table III. Although these figures are merely given for comparison and must be figured for each individual plant they are perhaps not far off from actual practice.

The purpose of preparing such a "cost sheet" was to enable us to compare with one another the cost of heating or melting 1 ton of steel in different furnaces and under different efficiencies, and was based finally upon the temperature of the metal, in other words to make the cost of heating metal a function of its temperature and furnace efficiency.

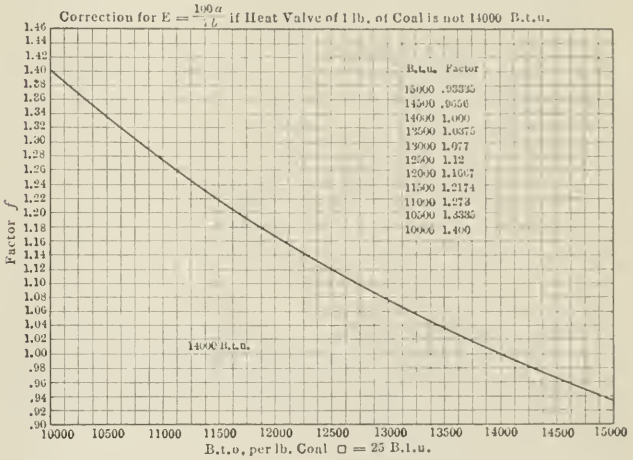


FIG. 3—CORRECTION FACTOR CURVE

To express the performance of any furnace by the amount of fuel used per ton metal heated, without paying attention to the heat in fuel and metal, does not give a clear picture of how much of the heat in fuel is actually absorbed in useful work, whereas, if we say, for instance, that a furnace has an actual efficiency of 10 per cent we come to realize at the same time the great amount of heat lost in such a process of heating or melting. We will try to find the causes of such losses and to improve the process.

Of two furnaces having similar construction, one may have a much lower fuel consumption than the other, yet after figuring their respective efficiencies the relation may just be reversed, on account of the poorer fuel value or different temperature of the heated material. The advantage of expressing furnace performances in percentage efficiencies can thus be seen.

Looking once more over the efficiency formulas we find that those for electricity and fuel oil are almost theoretically correct, whereas for those for wood and coal corrections will be necessary if the heat value does not

*See Richards, Metallurgical Calculations, Vol. I, p. 76.

†See Richards, Vol. I, p. 77.

Table III.—Costs of Heating or Melting
One Ton (2000 lbs.) of Steel in Different Furnaces Under Various Efficiencies and Fuel Prices

I. Fuel	II. Efficiency Formula	III. Fuel Costs Including Freight	IV. Additional Costs	V. Cost Formula in Cents	VI. Furnace Efficiencies in % 1%	2%	3%	4%	5%	6%	8%	10%	15%	20%	25%	40%	45%	50%	55%	60%
COAL:																				
Direct Fired	$E=\frac{100a}{7b}$	1 gr. ton = $3.00 (soft coal)	5 c for handling	$=\frac{1\text{ lb.}=.1562c \quad 2.232a}{E}$	2.232a	1.116 a	.744 a	.558 a	.4464a	.372 a	.279 a	.2232a	.1488a	.1116 a	.0893 a					
Powdered	$E=\frac{100a}{7b}$	1 gr. ton = $2.50 Gas Slack Coal	$1.25 for Pulverizer including interest and depreciation	$=\frac{1\text{ lb.}=.1674c \quad 2.3914a}{E}$	2.3914a	1.1957a	.7971a	.59785a	.4783a	.3986a	299 a	.2391a	.1594a	.11957a	.09565a					
Gasified	$E=\frac{100a}{7b}$	$3.50 Gas Coal	$1.25 to gasify including interest, etc.	$=\frac{1\text{ lb.}=.2123c \quad 3.033a}{E}$	3.033a	1.5165a	1.011 a	.7582a	.6066a	.5055a	.3791a	.3033a	.2022a	.15165a	.1213 a					
OIL:	$E=\frac{10a}{7b}$	1 gal. 2.5c	.5c per gal.	$=\frac{4.286a}{E}$	4.286 a	2.143 a	1.4287a	1.0715a	.8572a	.7143a	.5357a	.4286a	.2857a	.2143 a	.171 a					
		1 gal. 3. c	.5c per gal.	$=\frac{5. \quad a}{E}$	5. a	2.5 a	1.667 a	1.25 a	1. a	.8333a	.625 a	.5 a	.3333a	.25 a	.2 a					
		1 gal. 4. c	.5c per gal.	$=\frac{6.43 \quad a}{E}$	6 43 a	3.215 a	2.143 a	1.6 75a	1.286 a	1 072 a	.8038a	.643 a	.4285a	.3215 a	.257 a					
	b=gals.	1 gal. 5. c	.5c per gal.	$=\frac{7.86 \quad a}{E}$	7.86 a	3 93 a	2 62 a	1.965 a	1.572 a	1.31 a	.9825a	.786 a	.524 a	.393 a	.3143 a					
WOOD:	$E=\frac{100a}{3b}$ b=lbs. wood	1 cord Pine Wood $4.00 incl. handling		$=\frac{1\text{ lb.}=2c \quad 6.67a}{E}$	6 67 a	3.335 a	2.223 a	1.6675a	1.334 a	1.1117a	.8337a	.667 a	.4445a	3335 a	.267 a					
ELECTRIC POWER:	$E=\frac{58.617a}{b}$	1 kw-hr. = 1c.		$=\frac{58.617a}{E}$												1.4663a	1.3032a	1.173 a	1.0664a	9775a
		1 kw-hr. = 1 25c		$=\frac{73.27 \quad a}{E}$												1.8328a	1.629 a	1.466 a	1.333 a	1.2218a
		1 kw-hr. = 1 5c		$=\frac{87\ 926a}{E}$												2.1995a	1.955 a	1.7596a	1.5996a	1.4663a

correspond with the value given. Fig. 3 gives these correction factors with which $E = 100a/7b$ is to be multiplied if the coal used has a higher or lower heating value than 14,000 B.t.u. Similar correction curves can be plotted for wood, etc.

If the metal charged into the furnace has a higher than ordinary temperature, a will be represented by the difference of the two respective heat contents.

This I think is a good illustration of the usefulness of an efficiency formula instead of expressing the furnace work in the amount of fuel used. In such a case the latter would hardly mean anything to us.

Returning to our cost table, No. 3, a few explanations may serve to illustrate the use of the same. Under columns I and II different fuels and their efficiency formulas are given. In colume V the cost formulas were derived from the fuel cost and cost of preparation. This additional cost, on account of being more liable to changes, makes the cost formulas more fluctuating and can therefore be omitted if desired.

Under VI the factors are given with which a has to be multiplied to obtain the actual cost of heating or melting 1 ton of steel in a furnace whose efficiency was E.

E in percents is first figured from a and b and the cost looked for under E for respective furnace system and fuel cost.

(1) We readily see, for instance, that an oil-fired heating furnace (with oil at 2.5 cents per gal.) must have an efficiency of 10 per cent to compete economically with a hand-fired coal furnace of about 5., per cent efficiency.

(2) We can also say what price we are able to pay for a certain fuel (for instance oil) to compete with a coal-fired furnace of the same or higher efficiency (which is the reverse of example 1). In both these cases a was eliminated since we assumed that the temperature of the steel was the same in either furnace.

(3) Should the heating temperature of a furnace be increased or decreased for a certain period or should a new furnace be constructed of the same design as the one whose efficiency is known to us, but for a different temperature, we have for example:

$$\text{Cost } C_1 = \frac{E_1}{3.033a_1} \text{ (See cost formula.)}$$

$$\text{New furnace: Cost } C_2 = \frac{3.033a_2}{E_2}$$

If the temperatures are not too far apart we may assume:

$$E_1 = E_2$$

and therefore

$$\frac{C_1}{C_2} = \frac{a_1}{a_2}$$

in other words, roughly speaking, the cost of heating is in direct proportion to the heat content in steel and consequently to the fuel consumption

$$\frac{C_1}{C_2} = \frac{a_1}{a_2} = \frac{b_1}{b_2}$$

This assumption that the efficiencies of one and the same furnace were alike for moderate temperature differences is not correct since the losses by radiation and conduction also increase with higher temperatures and the conditions become quite complicated. It will also be influenced by the range of these two furnace temperatures from the flame temperature which in itself is not a constant.

These were only a few examples to show how this table can be used.

To facilitate this use it will be advisable after fuel

prices for special cases have once been settled, to construct the cost in form of curves, in which either fuel cost or a can be made variable, similar to the curves in Fig. 2.

Résumé.—In the foregoing the writer has tried to bring the question of comparing furnace efficiencies on a more uniform basis by means of the heat content in metal and he has given simple formulas by which this may be easily obtained.

Incidentally these formulas can also be used to develop a uniform system of cost comparison.

Noble, Pa.

Chemical Engineering in Nitrocellulose Manufacture

BY S. L. STADELMAN

This article bears on modern methods for the manufacture of cellulose-nitrate gun powder or nitrocellulose powder.

We shall avoid as much as possible material which can be gleaned from text-books and other magazine articles on the subject. Machines of standard make and patents on record, beyond merely sketching, will not be described in detail.

The quality of the American product, if we may diverge, is very high. Only one circumstance may mar it, namely, a possible failure in the manufacturing of a sufficiently pure diphenylamine (see Nitrocotton Powder Manufacture, under Mixing). The German product is a clear light yellow, the American is a dirty gray.

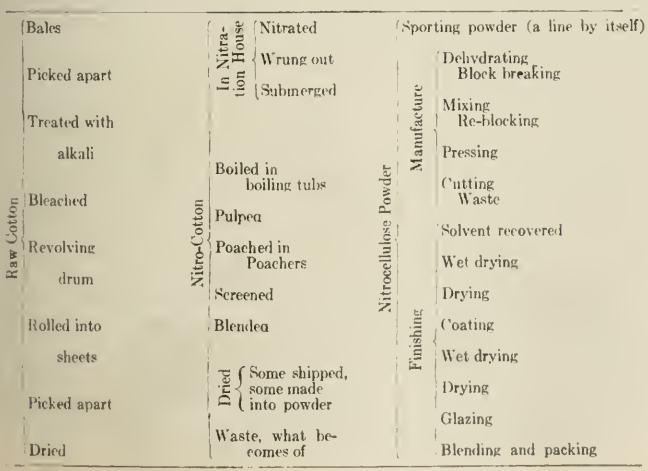
Only recently, in the latter part of April, there was recorded a big explosion in a Russian powder mill. We surmise that they are having the same difficulty. The material that exploded was probably nitrocellulose, and also, most likely, in a powder magazine. Rarely does a big explosion occur in a manufacturing plant where everything is run in small units on purpose to limit such possibilities. The Russians use nitrocellulose very largely. Even if it were another material that exploded, the fundamental cause could still be an impure member of the benzol series.

The cost of nitrocellulose powder manufacture, as near as we can judge, is between 35 and 40 cents a pound.

The manufacturing of nitrocellulose powder may be divided into several stages: the treatment of the raw cotton preparatory to its nitration; nitration and purification of this nitrated cotton preparatory to its being made into powder; the making of gun powder from the fluffy nitrated cotton, and lastly, the powder-finishing processes till shipment is made.

The accompanying flow table gives a fair idea of the whole process:

FLOW SHEET



Raw Cotton

For a raw material the shortest-fibered and cleanest, ripest cotton obtainable is used. The shorter the fiber the less the pulping (q.v.) required later to open the cells in order to free possible acid secretions.

The cotton comes in the ordinary compressed bale, which is opened and thrown into a picking or carding machine, where the fibers are picked apart from one another.

The cotton now receives a boiling of about eight hours in dilute alkali solution of about 1 lb. NaOH to every seven or eight gallons of water. The solution is drawn off and another free boiling with fresh water is given the cotton. Besides its dissolving effect on impurities the alkali saponifies the oils and the soap formed removes the dirt.

The cotton is next bleached to remove lignin substances that form unstable nitrates. This is done generally with calcium hypochlorite because of its cheapness. This material requires extra precautions in order to free the cotton of it, which is accomplished by a revolving drum screen through which plenty of water flows. Thus also is the dirt screened out.

In these two treatments care must be taken to avoid severity lest there should be formed either oxycelluloses with their resulting unstable nitro-compounds later, or hydrocelluloses with their different rates of nitration.

In order to obtain a uniform dry fluffy cotton, free of lumps which are hard to dry, it is next forced between heavy rollers and pressed into wide felt-like sheets. Again is the cotton, now in the form of sheets, subjected to a picking process—tearing fiber from fiber.

The cotton next takes about a thirty minute journey on an endless belt through the dryer at a temperature of 105 to 110 deg. C., and is dumped out with less than 1.1 per cent of moisture on an average. Sometimes though it contains 1.5 per cent or even 1.7 per cent, to overcome which the heat is driven upward, causing occasionally rather inconvenient but not seriously dangerous fires. Straightway on the cotton's dumping out it is packed in large tared tin cans, the lids are clapped on to avoid hygroscopic moisture and the cotton is ready for the weigher. The weigher sends each can to the nitrating house containing from 12 to 17½ lb. each of cotton, according to whether a nitro-cotton of high or low nitrogen content is being nitrated.

Regarding products of high nitrogen content or of low nitrogen content it may be said that throughout all the operations greater care and greater precautions are observed in proportion to the amount of the nitrogen content.

The cotton, scrupulously freed of all grease, oil, fat, lignin, water, dirt, etc., is ready for nitration.

Cellulose Nitrate

NITRATING

We shall call this nitro-cotton, since it is still cotton-like to the sight and to the touch.

We have now to deal with one of the most important parts of the whole operation, the nitration house and the nitrating of the cotton.

The nitrating house is a four-storied building with plenty of exits to outside fire escapes, plenty of windows to allow air circulation, and draft pipes sucking away the fumes from every fume-generating point. At some points, such as the neck of the nitrating pots, the suction of the draft pipes is shut off or opened by a valve connected to the lid; thus these draft pipes are opened only when necessary. The fumes collected are carried out and sent up a big terra-cotta standpipe, where they are condensed and collected for further use.

A nitrating house holds from four to eight nitrating

units. A nitrating unit has its parts on each floor of the building. On the fourth there is for each unit a vertical motor. The vertical shaft from the motor in passing down through the third story goes through the center of a square in each corner of which is set one of four nitrating pots. The shaft connects on the second floor with the bottom center of an iron basket of a centrifugal wringer. On the first floor or basement is the submerging pot directly under the wringer.

The motor on the fourth floor is under the control of the wringer-man on the second floor. Attached to the motor is a tell-tale indicating the number of charges the wringer runs off. The motor has two speeds: low or about 300 r.p.m., and high or 1100 r.p.m. Taking into consideration that the wringer basket has about 40 in. diameter it will be seen that at the high speed the circumferential velocity is about one and one-half times that of the old usage, or about 210 ft. per second, compared with the old-time usage of 140.

Each nitrating pot on the second floor has two agitators, interlocking with each other and revolving in opposite directions. The agitators have a low-speed of about 25 r.p.m. and a higher of about 60 r.p.m. The agitators are run by overhead shifting pulleys and belts connecting with shafts running lengthways of building and near the ceiling at both sides of the building.

The cotton ready for nitrating comes into the building at the third floor. Along with the proper "acid mixture" running in on top of it and with the agitators on the higher speed, the cotton is dumped into a nitrating pot. After thorough immersion has taken place the agitators are put on low speed.

After nitration the now nitro-cotton and the acid are drawn off by gravity from the pot, through a 6-in. pipe connected to its bottom, and run directly into, but against the side of, the slowly revolving wringer basket underneath. The wringer is speeded and the acid flung to the circumference of the basket runs through the holes therein and is collected in the basement below for future use. For a 12-lb. charge of raw cotton the wringer is run on high for one and three-quarter minutes and for a 30 or 35-lb. charge the wringer is on high for three and one-half minutes.

The acid wrung out, the wringer-man pulls up a valve plate, which surrounds the shaft and closed a circular hole in the bottom center of the basket. Through this hole with a brass-tipped pitch-fork he works the nitro-cotton. It drops directly into the submerging vessel below, where each fork lot is suddenly submerged by a heavy stream of water. From here the nitro-cotton and water are pumped to the boiling-tub house.

The wear and tear on a nitrating building is enormous. Parts for renewal must be zealously kept on hand and constant vigilance maintained against the least sign of a breakdown. As for fires, just as long as a good clean cotton is used they will be a rarity, taking it for granted that no dirt, oil, water, etc., is introduced into the cotton while nitrating and wringing out. It is said that a minute drop of water dropped in a charge when in a wringer will cause a fire.

So much may be said on the mechanical part. The chemical considerations next absorb our attention.

Since some part of the waste acids spoken of above would if revivified make the acid holdings on hand more than is necessary, this part is generally used for the manufacture of nitric acid. Oleum is used to revivify waste acids, which use reduces very considerably the loss from excess waste acids. Two or three kinds of fortifiers are used. The use of any special one on a particular case depends upon the kind of nitro-cotton being made, which in turn governs the proportionate loss between the acids in a charge and the water gain of a charge. On account of the variability of the loss or gain over the rectified acid in the sulphuric acid percentage of waste acids, a strong nitric acid fortifier is added first. This throws the H_2SO_4 percentage below what it should be if it is not already so. Now a 1 to 1, or some such other fortifier, can be used. Another consideration is in so running the waste acid batches that those which cannot be brought back to their original use can be changed to the nitration of another grade of nitro-cotton.

We shall in this article consider only three grades of nitro-cotton. First, a high-nitrogen cotton of from 13.30 to 13.45 per cent. Second, a middle grade nitro-cotton, pyrocellulose, of from 12.45 to 12.75 per cent of nitrogen, or even 18.85 per cent. Third, nitro-cotton of about 12.25 per cent N used as a component of gelatin dynamite.

The temperature of nitration of the high nitrogen material is from 15 to 20 deg. C. That for the lower nitrogens is from 35 to 40 deg. C.

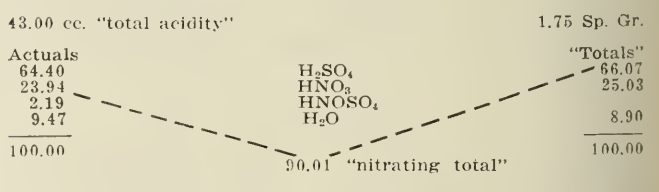
The time of nitration of the high nitrogen material is from fifteen to seventeen minutes. That for the lower nitrogen is about twenty-five minutes, although this is subject to a few minutes shortening. Both times are often considerably lengthened by delays, but without particular harm.

The cotton charge of the high nitrogen material is one can containing 12 lb. That for the low is two cans containing 17½ lb. each or 35 lb. Sometimes with an unusual fibered cotton 30 lb. per charge is used.

The theoretical yields of the three grades from the raw cotton is as follows: Multiply the raw cotton used by 1.65 to obtain the weight of the output of the high-nitrogen material. For the pyrocellulose multiply by 1.58. And for the 12.25 per cent material multiply by 1.50.

From the foregoing figures it will be seen that the theoretical output of one nitrating unit per day of twenty-four hours is 5702 lb. for the nitro-cotton of high nitrogen, 10,618 lb. for pyrocellulose, and the same for the low nitrogen product. If everything works smoothly the output of the two latter may be increased possibly 3000 lb. more each; since it is not injurious to cut down the time of nitration on them a few minutes. However, owing to breakdowns, etc., in actual practice the output of the high grade is about 4800 lb. a unit per day, and for the others it is about 10,000 lb. The percentage of acid mixture lost is between four and six. However, when the loss runs over 5 per cent, careful search should be made for leaks.

Because of its rough feeding to the nitrating pots, the quantity of acid put in each charge varies between 900 and 1000 lb. But there is no such wide diversity allowed in the composition of the acid mixture itself. We subjoin a typical analysis of an acid mixture used for making high-grade nitro-cotton:



This nitrating total is derived by adding together the two percentages indicated by the dotted lines. The right-hand column of percentages is deduced from the number of cubic centimeters of the total acidity and the specific gravity. The $HNOSO_4$, iron salts, etc., are not reckoned with in this column, therefore the H_2SO_4 and HNO_3 are high and the H_2O is low. In the "actuals"

column the HNO_3 and $HNOSO_4$ have been determined by nitrometer and by titration respectively, their sum subtracted giving the actual H_2SO_4 direct from the total acidity.

The "nitrating total" is the governing consideration. The actual nitric acid is generally figured at 24 per cent for a high-grade nitrating mixture for nitrating high-grade nitro-cotton. But if it runs under or over, then the "totals" H_2SO_4 will have to run a corresponding percentage in the opposite direction in order to keep the nitrating total around 90. An acid mixture of this analysis ought to give a product of about 13.37 per cent N, $\pm$ 0.07.

In the acid mixture used for making pyrocellulose the HNO_3 is kept close to 19.30 per cent and the nitrating total at 83.75. Sometimes the nitrating total may be run up to 84 when the fiber to be nitrated is coarse or tough. For dynamite nitro-cotton the HNO_3 is about 26.5 to 27 per cent and a nitrating total of 83.30. This means a low H_2SO_4 content.

Regarding the water content the principle is to maintain it as high as compatible with obtaining the desired nitrogen percentage. High water content tends to increase the solubility of the product (see Blending).

On leaving the nitrating house the submerged nitro-cotton is pumped to the boiling-tub house. A tub has a capacity of about 1200 lb. Everyone is familiar with them, with their double bottoms, the uppermost one perforated and with perforated lead steam coils lying between.

After draining off the submerging water and adding fresh, the high-grade nitro-cotton is given five boilings here altogether. The first is for thirty hours, the water is drained off through the perforated bottom, fresh water added, brought to a boil, and boiled for five hours. Three more five-hour boilings follow, changing water each time.

The pyro-cotton receives first a twenty-five-hour boiling, then follow three five-hour boilings, again changing the water each time.

The dynamite-cotton receives an entirely different treatment. In a separate tank especially for the purpose water is heated to 70 deg. C. and no heat or steam whatsoever besides the preheated water is allowed in the tubs where the dynamite cotton is. The first steeping with this 70 deg. water is for one hour. The water is run off and more pre-heated water added. This, the second steeping, is for two hours, the third steeping is for three hours, the fourth is for twenty-four and the fifth is for twenty. Ten pounds of Na_2CO_3 is added to the first steeping water.

Counting all the times of boiling, draining off, filling up with fresh water and bringing the water to boil, the sum in the case of high grade is about 64 hours, for pyro-cotton it is about 52 hours and for dynamite cotton it is about 55 hours. To these times ought to be added about 4 to 5 hours more in each case to have a fair idea as to how long a charge of each grade is in the building.

A fair amount of nitro-cotton is strewn about tubs on the floors of the building and becomes waste. It is collected and thrown into a tub by itself. Eventually it follows through the same treatment as the pyro-cotton till it joins the sporting nitro-cotton in poacher house. It finally ends as sporting powder (q. v.).

In draining the boiling waters from the tubs through the perforated bottoms, material is again lost. Big settling troughs, through which the waste water is led, are built to collect this material. After a sufficient quantity has collected, it usually is sent direct to the sporting nitro-cotton poachers in poacher house.

About this stage the future blending is beginning to be looked after. A careful tracer kept of every tub lot of nitro-cotton shows, by referring to the analysis of acid mixtures as per number given on card, and referring also to the characteristics of the cotton, etc., etc., about what percentage of nitrogen the nitro-cotton will have. On this basis it is generally several tubs of high nitrogen pyrocellulose (about 12.70 to 12.80 per cent) which are selected for the future blending. Outside of giving the pyrocellulose in these tubs one hour less pulping (to be known as seven-hour pyrocellulose) it is not treated differently from ordinary pyrocellulose used for cannon powder.

After these boiling treatments the nitro-cotton is, after draining, forked out of the tubs into high-sided cars and delivered to the pulping house.

PULPING

The pulping machine used is the same as is employed by paper manufacturers. A pulping machine or "beater" will have about one-fifth less capacity when pulping nitro-cotton compared with paper pulp. The horsepower required is considerably greater.

The washer connected with the beater carries off a good deal of fine nitro-cotton in liquid suspension. This liquid is run into large circular settling vats of iron. The waste from the floors is also dumped into the settling vats. In fact, they are the recipients of a great deal of waste from various sources, as we shall see as we go along. What is done with this waste will be told under sporting powder.

The beaters are set down in the floor, which makes it easy to dump the nitro-cotton from the cars into them. During the course of the pulping of a charge enough Na_2CO_3 is added to make a slight alkalinity.

The high-grade nitro-cotton is pulped twelve hours—rarely less. This length of time is allowed it so that it may be fine enough to incorporate well in the colloid (see mixing) so that it can more easily pass through the fine screens of the macaroni press. In pulping to such fineness care must be taken that the material becomes not so fine as to clog seriously in the dehydration press (q. v.). This is overcome somewhat by allowing its co-constituent (seven-hour pyrocellulose) to retain some of its coarseness by not pulping it so much.

Pyro-cotton is pulped eight hours ordinarily. Dynamite cotton is pulped for eleven hours. Boiling water cannot be used on dynamite cotton at any stage; therefore, it must be well pulped to assure freedom from acid, salts, etc.

In the pulping of high-grade and pyro-cottons we do not know of any case where hot water is in use, although it is supposed to be a considerable advantage.

From the beaters the pulp-filled water is pumped through pipes to the poachers.

POACHING

Poachers are large, deep, round wooden tanks with facilities for introducing steam into them, for draining the water from the top downward and for stirring the charge. They have a nitro-cotton capacity when in a desirable thickness of water suspension, of about 7000 lb.

When a poacher is first filled the charge is allowed to settle, the supernatant water drained off and clear water added. High-grade nitro-cotton receives four five-hour boilings. Twenty pounds of Na_2CO_3 is added the first boiling and 15 lb. the second. The stirring is kept up during the boiling. After the boiling the high-grade has ten cold-water washings. Each washing is stirred for a half hour.

Pyro-cotton is treated according to the U. S. Government specification (see page 191 of "Military Explo-

sives" by Weaver, 3rd edition), except that 35 lb. of Na_2CO_3 are added the first boiling. The sampling and testing is carried out substantially the same as described in Weaver's book, page 192.

Dynamite-cotton receives ten cold-water washings only. All washings from this and the other nitro-cottons are run into the big iron settling vats.

It is in the poachers that one of the two principal blendings is done. The object of blending is to obtain a product of definite qualities, but the blending at this stage is made necessary by the desire to obtain a small-arms colloidal powder high in nitrogen content. Nitro-cotton of 12.85 per cent nitrogen can be made that will be soluble in a mixture of thirty-six parts alcohol and sixty-four parts ether, and a colloid powder be made of it, but above this percentage of nitrogen the solubility rapidly decreases till at 13.40 per cent N only about 8 per cent + is soluble. Now, to obtain a powder of 13.20 per cent N, the 8 per cent soluble high-grade is blended with the entirely soluble pyro-cotton (seven-hour pyro) to make a mixture of about 29 or 30 per cent soluble, which is enough to give when treated with ether-alcohol, a good colloidal body which will encase the non-colloids.

Also in blending it is not desirable to attempt to cut down on the quantity of the non-colloids. They should rather be maintained as nearly as possible at a definite percentage, for it is the presence of these fine detonating particles which gives the powder extra explosive force.

The mechanical part of the blending is done simply by taking a predetermined weight of wrung-out seven-hour pyrocellulose and dumping it into a poacher of high-grade nitro-cotton containing a known weight and stirring them thoroughly together.

DRYING

Centrifugal wringers are again made use of, this time to drive out the water. The rather thick water and nitro-cotton is pumped over the wringer through a pipe line which has side connections easily handled by the wringer man. Again the waste water goes to the iron settling tanks. The wringer baskets are much smaller —possibly 8 in. less in diameter—than those in the nitrating house; consequently their circumferential velocity is much less although they make the same number of revolutions per minute.

With the high-grade—now, a high-grade and pyro blend—and the pyrocellulose it is desirable to wring the water content down to as low as 30 per cent. The lower the water content the greater the saving of alcohol in the dehydration. With seven-hour pyrocellulose and dynamite cotton it is not so necessary. The first goes back to a poacher, anyhow, and the latter has to be only dry enough for a drying barrel to handle it.

The blend of high grade and pyro and the pyro are forked through the bottom of the wringer into a blending barrel. When full the barrel is turned over a few minutes, opened, and the contents dropped into a car. Thence they are hauled to steam-heated storage sheds and are ready for dehydration.

Occasionally the pyrocellulose is taken out of its cars, put into a packing press, pressed into oblong blocks, packed in zinc-lined boxes and shipped as pyrocellulose.

The dynamite cotton, after dumping in cars, is taken to a large revolving drying barrel where it is dumped in and dried till the moisture is brought down to 25 per cent. From here the dynamite is sifted through a large mesh screen, pressed into zinc-lined boxes and is ready for shipment to a dynamite manufacturing plant.

SCREENING

In pumping the mixture of water and nitro-cotton from the poachers to the wringers or from one poacher to another according to exigencies it is screened to take out the knots, the larger sized fibers, sticks, dirt, etc. The bottom of the screen is vibrating up and down and is made of metal full of short, narrow slits.

Manufacturing and Finishing

SPORTING POWDERS

We now come to a branch which is practically by itself.

We have had occasion before to speak about big, round iron settling vats. It will be remembered that the very greatest bulk of this was that which crept through because of its fineness. In fact, it is so fine that alum has to be used to insure its settling to the bottom of the vats. This fineness is what fits it for sporting powder. The nitrogen in this low-grade nitro-cotton runs about 12.40 per cent.

After a vat is full the fine nitro-cotton settled and the supernatant water drawn off, the nitro-cotton is pumped with a little water into a poacher. Here it is given two five-hour boilings, followed by the customary ten cold-water washings. Thence it goes to the wringers and is wrung out to about 38 per cent H_2O. After adding enough high-grade nitro-cotton to it to bring the nitrogen to about 12.50 per cent, it is ready for turning it into powder.

The principle of a sporting powder is simply to make grains of nitro-cotton, which on the outside are hard and impervious, yet have somewhat the explosive effect of uncolloided nitro-cotton.

The manufacture of E. C. powder is familiar and we do not know of any improvement on its manufacture within recent years. Some firms use Chilian saltpeter instead of the potassium salt, which is apparently a good idea, since the grains are water-proof. Aurine is still used in the coating and ether-alcohol in the gelatinization of the water. The speed of revolution of the nitro-cotton granulating drum regulates the size of the grains.

Another powder is made somewhat as follows. The nitro-cotton is held in suspension in a solution of 6 per cent calcium nitrate and 20 per cent potassium nitrate by bubbling upward through it a mixture of benzene (C_6H_6) 60 per cent and amyl-acetate 40 per cent. The size of the grains formed depends on the rate of the bubbling. The grains must have a certain weight and size and be granular and round. The whole solution with grains is carried over and screened. The amyl-acetate and benzene are recovered by distillation.

Frequent ballistic tests are made of this powder.

DEHYDRATION

In the process of dehydration all materials are tested alike except that sometimes an exceptional or say a balky lot may be filled with a different quantity of alcohol preparatory to using a different quantity of ether in the mixing house, thus using a differently proportioned colloiding mixture.

The principle of a dehydrating press is as follows: The nitro-cotton is dumped in and pressure applied to drive out as much water as permitted by the space demanded by the quantity of alcohol that is wanted in it. Ordinarily this pressure is about 3000 lb. Finally alcohol introduced under pressure at one end drives the water ahead of it out of the other end. The pressure is broken, the alcoholic nitro-cotton cake is released, test-weighed and canned immediately to avoid evaporation.

From the storage sheds (see Drying, 3d paragraph) the cars of nitro-cotton are put directly in the dehydration house. A definite quantity, enough to make 40 lb. of dry nitro-cotton, is weighed and dumped into the press. If the weight of this, including the water con-

tent, is 57 lb., then 7½ to 8 gal. of alcohol will be required to dehydrate it. If the weight is 61 to 63 lb., then about 10 gal. are required. This shows the value of a low water content. It saves steam and the wear and tear on the apparatus in the recovery by distillation of the alcohol.

The time of a complete cycle of the dehydrating press is about three minutes and fifteen seconds to three minutes and thirty seconds. It has been brought down to an average of two minutes and forty seconds. These operations (see also macaroni presses) depend so entirely upon the working conditions and the momentary efficiency of the plant that it is hard to give definite data.

Although the U. S. specifications allow the use of alcohol as low as 92.3 per cent by weight, yet the usual strength is 95 per cent. The quantity of alcohol left in each dehydrated block is between 12 and 24 lb., according to what might be called the "workableness" of the nitro-cotton that is being handled at the time. The average quantity of alcohol left in it is about 16½ lb.

BLOCK BREAKER

The alcoholic cakes or blocks of nitro-cotton have to be broken up and rather finely sifted so that they will colloid better in the mixers. The block-breaker does this work. It doesn't need be described. The workmen break up the blocks and small lumps on the floor, which is lead covered.

MIXING

A mixer charge comprises, with the 60 lb. or more blades is familiar to everyone. The mixers are surrounded by a cold-water jacket to prevent overheating. But the coldness of the water has also a great effect on colloidization—cold accelerates colloidization and helps to colloid nitro-cotton otherwise not colloidable, and it should be allowed for accordingly. To prevent evaporation of the solvent there is a heavy air-tight lid. The whole mixing machine with its charge is so arranged that it can be dumped of its contents.

At the side of and above a mixer is a small scale with a tared container on it for the weighing of the ether. In this ether there has been dissolved diphenylamine in sufficient quantity to leave one-half of one per cent of it in the finished powder. Diphenylamine is, as everyone knows, the stabilizer. Its agency is to absorb the acidic decomposition products of the nitro-cellulose, thus preventing their deleterious effects, and also, by not permitting their escape, it helps to maintain the ballistics of the powder.

A mixer charge comprises, with the 60 lb. or more of alcohol impregnating it, 200 lb. of nitro-cotton in cans fresh from the block breaker. Enough ether, while the mixer is running, is added to make up at least 64 per cent of the total solvents used, allowing for alcohol evaporation. The mixing is continued thirty minutes or more till the material is suitable for the macaroni presses. To tell when this stage has been reached takes an experienced man. Speaking for himself the author must say that although he has examined these charges repeatedly, yet he can hardly give specific rules to govern telling when this stage is reached. The lumps must have homogeneity—no uncolloided material inside—and there is a certain general consistency which is the outcome of so much solvent on so much soluble nitro-cotton. Sometimes an operator is not satisfied and he adds more ether. Rarely, although it would not be necessary if properly blended, acetone in small percentage is added to increase solubility. Nitro-cellulose powder colloided with acetone is apt to have irregular pressures.

So far we have described the mixing as if the high-grade pyrocellulose mixture and the pyrocellulose nitro-cottons were treated alike. This is so, with the exception that graphite is incorporated in the high-grade pyrocellulose mixture. This is the material of the higher explosive force and is used only for making small arms powder, which means it is made into very small grains. These small grains, unless they had some such material as graphite to make them conducting, would become charged with static electricity which would make them inconvenient for handling and for examination. The larger grains for the larger calibred guns are coated later with graphite.

REBLOCKING PRESSES

The charges from the mixers are first taken to a press where they are pressed into an easily handled cylindrical shape of the right diameter to fit the macaroni presses. The whole mixer charge is not pressed into one block, but into two or three, all of which make a macaroni press charge.

MACARONI PRESSES

(GRAINING PRESSES OR FINISHING PRESSES)

Ordinarily these presses are horizontal. At the end through which the colloid is pressed is a heavy perforated plate set in a heavy band locking door on hinges. This door swings open and the charge is put in and before closing a fine copper screen, of about 60 mesh, we should judge, is put on the inside of the perforated plate.

The colloid is forced through the fine copper screen, through the perforated plate, then through ten to twenty dies, and is carried away from each die by a downward sloping smooth tin tube which coils up the now string-like (although for big guns some is rope-like) colloid in the bottom of round boxes. When a box is filled, it is delivered to a cutting machine and another box is substituted in its place.

It is hard to describe a die and to give a good idea of how it works. The part of the die nearest the press consists of a small round perforated plate, from the center of which, outward and away from the press, projects a needle—to take a simple case—clear through the center of a funnel. A cross-section is shown in Fig. 1.

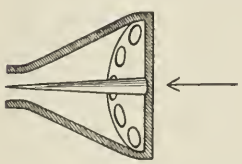


FIG. 1—SECTION OF DIE

The arrow indicates the direction of flow. The colloid squeezed through the holes in the perforated plate is compressed around the needle in the funnel chamber and on going through the outlet it has the desired hole lengthways throughout the center.

The area of the holes in the die must be at least one and one-fourth times the area of the cross-section of the die, lest the part compressed in the funnel should not be thoroughly enough compressed, resulting in an imperfect grain. The initial pressure on these presses is about 2700 lb. and the pressure mounts to about 3300 lb. at the end. A wide divergence is an unfavorable indication of the quality and purity from dirt.

By the output of these presses may be judged the efficiency of the whole plant. By "output" is meant quantity and quality. True, other operations are yet to follow, but they affect the output not so much as the prior operations, and neither do they indicate so well as the presses the quality of the prior operations.

The efficiency capacity of a press is about sixteen charges for twenty-four hours working time, but such an output is obtainable only by the exercise of high intelligence by every man connected with all the prior

operations. If the output of the presses be on an average of thirteen and one-half charges every twenty-four hours it could be classed as highly satisfactory. Ordinarily the run is nine to eleven charges. These figures for efficiency capacity apply to the output of a press that is pressing small-arms powder. For larger arms the output mounts as high as four times the above figures.

CUTTING MACHINES

In this machine the colloid strings, coiled up in round boxes and fresh from the presses, are fed between rollers, then through guiding holes, immediately on the far side of which they are cut into definite length grains by knife-edges set in the periphery of a revolving disk. The speed of the feeding, which is rarely varied, and the speed of the disk govern the length of the grains. The proportion of the parts of the grains is specified in the United States Government's tests. The sizes of the grains required to meet the specifications for the muzzle velocity desired and maximum pressure allowable is a subject beyond the scope of this article. However, we understand there have been one or two good books recently published on interior ballistics.

From the cutters the grains are collected in bags and sent to the solvent recovery. With the bigger grains it pays, even while the grains are collecting, to make arrangements to save the large amount of solvent evaporation from them.

From the presses and from the cutting machines there is a considerable waste of colloid nitro-cellulose. It is thrown into covered cans and when a sufficient amount has accumulated it is put in a small mixer, specially used for this purpose and mixed over again.

SOLVENT RECOVERY

The solvent recovery building is a long building with many brick fire-limiting walls. With handy connections, there are in each section pipes carrying warm air and other pipes carrying a refrigerating mixture. In each section is a narrow-gage track.

The solvent recovery cars are specially constructed. They are rendered vapor-proof by water sealing of the lids. Lengthways of one side is an air-warming apparatus which causes the air to rise on that side. The air flows over and down among the powder grains collecting the ether and alcohol vapors on its way. At the bottom the air strikes refrigerating coils and promptly gives up its vapors. The powder is in shallow trays, with copper screens on bottom, and set one on top of the other. The recovery process is continued till the small amount which would be recovered does not pay.

The ether and alcohol mixture that is recovered is sent back to the ether house, treated with H_2SO_4 and all made into ether.

WET DRYING

It sounds rather paradoxical to speak of wet drying, but the idea is to maintain the powder under water at 65 deg. C., in order to "boil" out the ether and alcohol mixture the more effectively. The principle of using cars is employed again, but the powder is set in deep copper screen baskets. What the length of time of this treatment is we don't know. It is probably not very long.

DRYING HOUSE

Here the water is dried off the grains.

COATING MACHINES

These give each grain a coating of trinitrotoluol. Which one of the trinitrotoluols it is we are uncertain.

This matter of coating the grains has a great deal of significance. There are probably three or four reasons for doing it. If, as it seems to be, America, by such a simple expedient, improves nitro-cellulose powders, without the addition of injurious ingredients, then we can claim some originality for ourselves. What England has attempted to do in her cordite and France in her nitrate powders, America does in a simple manner.

WET DRYER, DRY HOUSE, GLAZING BARREL

We have now another wet-drying process, this time to take out the solvent used in the coating process. It must have been a rather heavy coat which was applied in the coating process.

Again the water is dried off in a dry house.

The glazing barrel is used for glazing every grain with graphite.

Graphite has two uses; it protects the grain from sudden shock, and makes a conducting skin to carry off static electricity caused by friction of the grains over each other. Sometimes, before this skin is put on, the powder will take fire in an inexplicable manner.

BLENDING AND PACKING

The high-grade and pyrocellulose rifle powder blends are blended in the poachers as we have seen. The pyrocellulose cannon powders have so far come through with a percentage of nitrogen running between 12.45 and 12.75. The scheme is to blend these powders to meet the government specifications of 12.60 per cent, $\pm$ .01 per cent. After taking two lots of powder and calculating the proper proportions in which to mix them, this is done by putting those proportions of the powders in a square wooden funnel with an opening at the bottom. This opening is opened and the powders are allowed to run into another wooden funnel beneath. This in turn is opened, running the powder into another funnel, etc., till the powders are thoroughly mixed together, or about three or four times altogether.

Regarding packing, see United States Government specifications.

Library Service Bureau of United Engineering Societies

The United Engineering Library (Engineering Societies Building, 29 West 39th Street, New York City, 12th and 13th floors) is installing a Library Service Bureau along the lines of the former Library Service Bureau of The Chemists' Club. For the purpose of inaugurating this service, the three founder societies of the mining, mechanical and electrical engineers will provide the necessary funds, but the bureau is expected to become self-supporting.

The object of the bureau will be to place the facilities of the United Engineering Library at the disposal of anybody anywhere. Its work will consist in supplying reference cards on articles published anywhere on any special technical subject desired, in supplying copies of articles or of parts of books, in translating articles from foreign languages, making searches on any technical subject, etc. This work will be done at cost. Mr. E. Gybbon Spilsbury is the chairman of the "Library Service Committee" which will act in advisory co-operation with the executive committee of the library board of the United Engineering Society, of which Dr. Samuel Sheldon is the chairman.

Burma is the principal tungsten-producing country of the world, the United States coming second with about half the Burmese production. The bulk of the domestic output comes from Boulder county, Colorado.

The Relative Efficiency of Various Amalgams in the Recovery of Gold

BY FRANCIS A. THOMSON AND ROBERT KEFFER

In these days of the almost universal cyanidation of gold ores, the ancient and honorable process of amalgamation would appear to have been relegated to the rear. This is truer, however, of the literature of gold metallurgy than of the practice of the art, for we find that in 1913 21.5 per cent of the gold production of the United States was recovered by amalgamation.[1]

It would seem, therefore, that although somewhat unusual and contrary to the present vogue, one need make no apology for a discussion of certain important principles involved in the recovery of gold with the aid of mercury. Many years ago C. H. Aaron[2] stated that he had investigated zinc and cadmium amalgams and had found cadmium-amalgam especially to be remarkably free from tarnish under conditions where mercury-coated copper plates were quickly discolored.

This was the starting point of the investigation here reported. It was thought well, however, to extend the research to include a determination of the efficiency of various amalgams from the point of view of gold recovery, as well as of resistivity to film formation.

The senior writer of this article suggested the investigation and in a general way guided the research; he has also edited the report for publication. Further than this he disclaims any credit for the work done or the conclusions drawn.

As the first step in the investigation a number of amalgams of the commoner metals were prepared. These were then placed in turn on copper plates and the ore passed over the amalgamated plates a standard number of times under standard conditions. Samples were taken of the pulp during the first, third and fifth passage over the plates, and the samples were assayed to determine the amount of gold removed. The difference between this assay and the assay of the original ore was considered the extraction in each case.

Two tests were made to determine the number of passages over the plates necessary to secure the maximum extraction. The ore was run through the apparatus ten times and samples taken during alternate runs. In both cases no further change in the assay of the tailings took place after the fifth passage so the succeeding tests were run through only five times.

To further investigate the properties of the amalgams, a series of tests was made under difficult conditions. The ore was mixed in turn with manganese sulphate, zinc sulphate and ferrous sulphate, and each mixture passed over the plates five times. Two samples were taken—after the third and fifth passage —and assays were made as in the first series of tests. The sample of the first passage of the ore was omitted in these tests, as it had previously been found that little gold was removed by the initial run over the plates. A sulphide ore was also tried with a number of amalgams, but it gave such small extraction and yielded such inconsistent results that further tests along this line were abandoned.

Preparation of Amalgams

The common metals that amalgamate with ease are: gold, silver, zinc, tin, cadmium, lead and bismuth.[3] With the exception of bismuth and with the addition of sodium, potassium, aluminium and magnesium these metals constituted the list selected for the tests. Of these, potassium, aluminium and magnesium yielded amalgams of such an unstable nature that they were unsuited for use on the plates. The tests were, therefore, confined to the remaining seven metals. The method of preparation employed varied greatly and each metal will therefore be discussed separately.

1. **Silver Amalgam.** The silver amalgam was prepared according to the method given by Richards.[4] The reaction was practically complete in twenty minutes and the final amalgam (composition, silver 32 per cent, mercury 68 per cent) was a thick paste.

2. **Gold Amalgam.** The gold amalgam was prepared by dissolving pure gold, beaten into thin plates, in boiling mercury. It was found that the gold dissolved very slowly at ordinary temperatures, but went into solution in a few minutes when the mercury is near its boiling point. Fifty grams of mercury were used with 4.121 grams of gold and the resulting amalgam was pasty. On standing a very thick amalgam settled in the bottom of the tube, the remainder being perfectly liquid.

3. **Sodium Amalgam.** In the preparation of sodium amalgam 100 gm. of mercury were warmed in a casserole, and sodium metal added in small pieces, about the size of wheat grains. The sodium combines violently with the mercury, with evolution of yellow light; but as more sodium is added the reaction decreases in violence. Towards the end the mercury must be heated to boiling and the sodium stirred in. A total of 5.4 grams of sodium was required to saturate the mercury. On cooling the amalgam becomes hard and brittle, breaking with a rough fracture. It is soluble in mercury in any proportion and keeps indefinitely in a tightly corked bottle.

4. **Potassium Amalgam.** The potassium amalgam must be prepared in a test tube or other vessel with a narrow opening, which exposes but little surface to the air. In an open dish the potassium is oxidized to a greenish powder, practically as rapidly as added. The reaction between potassium and mercury is much less violent than that with sodium and the mercury must be hot to start the combination. The potassium was added in small, clean pieces, about the size of wheat grains and combined readily with the hot mercury with flashes of violet light. Towards the end of the reaction violent stirring and a temperature about the boiling point of mercury were required to cause combination. The mercury required 5.1 grams of potassium per 100 grams mercury for saturation (at boiling point of mercury). On cooling in the closed tube the amalgam hardened to a solid mass. When the cold amalgam was exposed to the air by breaking the tube decomposition set in immediately. The potassium oxidized very rapidly, occasionally with flashes of flame, forming a dull, greenish powder and liberating mercury. On account of its unstable nature this amalgam was not used in the tests.

5. **Lead Amalgam.** This was prepared by dissolving pure lead foil in warm mercury. It went into solution very readily, yielding a homogeneous fluid, which solidified to a pasty mass on cooling. On standing several hours the amalgam showed a marked tendency to separate into a thick, pasty amalgam and a very fluid amalgam, in a manner similar to gold amalgam. Composition—lead 50 per cent, mercury 50 per cent.

6. **Tin Amalgam.** Tin amalgam is prepared by dissolving tin foil or granulated tin in warm mercury. It resembles lead amalgam in its properties, except that it showed no tendency to separate as in the case of lead amalgam. Composition—tin 43 per cent, mercury 57 per cent.

[1] Mineral Resources 1913, Part I, p. 882.
[2] Eng. & Min. Jour., Vol. 48, p. 118.
[3] Schnabel. Handbook of Metallurgy. Vol. II, p. 254.
[4] Richards. Textbook on Ore Dressing. p. 114.

7. **Zinc Amalgam.** This amalgam was prepared by grinding 20-mesh powdered zinc in an agate mortar with mercury. Forty grams of zinc were dissolved in 100 grams of mercury, after about two months grinding. On standing the amalgam solidified to a hard, brittle mass, readily soluble in warm mercury.

8. **Cadmium Amalgam.** Pure cadmium in the form of ¼-in. sticks was dissolved in warm mercury. The cadmium went into solution very readily, being completely dissolved in five minutes. On cooling, the amalgam solidified to a hard, brittle, crystalline mass, which broke with an uneven fracture. It is very stable. Composition—cadmium 32 per cent, mercury 68 per cent.

9. **Aluminium Amalgam.** This amalgam was prepared with considerable difficulty. The usual methods of preparing amalgams were tried without success. The aluminium, in the form of dust minus 150-mesh, was boiled in mercury, but did not combine. Prolonged grinding with mercury in the agate mortar was next tried and failed to form any amalgam. The mercury was then heated with aluminium powder and dilute hydrochloric acid over night, without results. A quantity of aluminium strips was melted in a muffle at about 700 deg. Centigrade and the molten metal poured into cold mercury. This resulted in the formation of considerable liquid aluminium amalgam. The amalgam produced by this means was very unstable and, on cooling, a film of alumina formed over the surface and rapidly increased to a thick, fluffy coating.

To determine whether this instability was an inherent property of the amalgam or due merely to the high temperature of formation by addition of molten aluminium, a second lot of amalgam was prepared cold by treating sodium amalgam with a suspension of aluminium powder in water, as mentioned by Schnabel for the preparation of iron amalgam.[5] On standing twelve hours the sodium amalgam was completely decomposed with formation of sodium hydroxide and liberation of hydrogen and mercury.

$$Hg_xNa_y + yH_2O = xHg + yNaOH + \frac{y}{2} H^2$$

The liberated mercury combined with the aluminium to form aluminium amalgam. This amalgam was divided into two parts. Part 1 was tested qualitatively for aluminium and showed a large amount present. Part 2 was exposed to the air in a test tube and in six hours it had formed a "tree" of bulky alumina above the amalgam. This tree was of the same diameter as the button of amalgam, an inch and one-fourth long, and free from the tube on all sides. It was light gray, fairly coherent and showed to a remarkable extent the unstable character of the amalgam. The remaining mercury in part 2 was then tested for aluminium and showed only a trace of that metal. This amalgam was not used on account of its unstable nature.

10. **Magnesium Amalgam.** This amalgam is easily prepared by shaking the powdered magnesium in very hot mercury in a test tube. The amalgam is of a bright, silvery color. It was very unstable and on cooling decomposed rapidly, yielding a black powder (probably magnesium oxide) and mercury. It was not possible to get enough magnesium to combine to produce a solid amalgam on cooling in a closed tube. This amalgam was not used on account of its unstable nature.

Preparation of the Ore

The ore used was a quartz carrying free gold from the Anaconda claim, Ten Mile Camp, Idaho County, Idaho.

A 50 lb. lot was run through small rolls and then through a Braun pulverizer so that all passed through 40 mesh. It was then sampled very carefully by coning and quartering, followed by riffles.

As determined by a large number of check assays, the ore averaged 2.49 oz. gold and 2.7 oz. silver. The silver was not considered in the subsequent work.

Design of Apparatus

After considerable experimenting with an apparatus designed to change the direction of pulp flow after every 18 in. of plate length, it became apparent that such a machine was not a success. A second type of apparatus was, therefore, designed, consisting of a straight launder, in two 6-in. x 51-in. sections, with a drop of 2 in. between sections. The bottom of the launder was covered with six 6-in. x 18-in. copper plates, overlapping at the ends in the direction of pulp flow. The launder had a uniform slope of 1½ in. per foot.

The pulp was fed onto the upper plate from an 8-gal. conical sheet-iron tank, through a ½-in. valve. On account of the narrow plates used no spreader was found necessary to secure an even layer of pulp over the plates. The pulp, after passing the plates, flowed into a tailing tank of a capacity of 5 gal.

Preparation of the Plates

The plates were amalgamated as recommended by Richards.[6] They were rubbed with fine sand with a block of wood until the plates had a uniform red surface, dried and polished. A mixture of 10 sand to 1 ammonium chloride was then made, slightly dampened, and mercury was sprinkled into it. This mixture was rubbed into the plates until they had a uniform, mirror-like surface. They were then allowed to stand several hours and the green stains which developed scoured off and re-amalgamated. The plates were again allowed to stand and the foregoing process repeated until a resistant coat of mercury was obtained.

The plates covered with the different amalgams were prepared as follows: The plates were cleaned and amalgamated with pure mercury. The amalgam to be used was then diluted with mercury until it reached a thin pasty condition, and painted on the surface of the plates in a thin coat. All six plates were given an even coating, no attempt being made to give the top plate any different treatment from the others. When necessary the plates were scrubbed until the amalgam was of uniform texture.

After the runs with each amalgam the plates were cleaned up by first scraping with a piece of belting nailed to a small wooden block and lastly by scraping with a smooth piece of rubber stretched over a metal straight-edge. They were then scrubbed with sand and amalgamated for the next run. The gold amalgam was run last to avoid the possibility of salting the tailing from any other run.

Method of Operating

In order that all the tests might represent the same conditions, it was necessary to decide upon a standard method of procedure for use throughout the experiment.

The thickness of pulp which gave the best results was found to be 8 lb. of water per pound of ore, and this dilution was closely followed in all the tests. The pulp was stirred by hand in the tank until it reached a nearly uniform thickness; the valve opened and stirring continued while the pulp flowed over the plates.

The number of times that it was necessary to run the ore over the plates to secure a good extraction was

[5] Schnabel Handbook of Metallurgy. Vol. II, p. 254.

[6] Richards. Textbook on Ore Dressing. p. 114.

determined experimentally with pure mercury and with lead amalgam. These were run ten times with assays as shown in Table No. 1.

TABLE No. 1

	1st Run		3rd Run		5th Run		7th Run		10th Run	
Mercury	2.58	2.64	0.60	0.60	0.56	0.56	0.56	0.60	0.56	0.58
Lead Amalgam	2.56	1.82	0.80	0.80	0.80	0.78	0.80	0.76	0.82	0.80

From Table No. 1 it appears that no further extraction resulted after the fifth run and the remaining tests were therefore passed over the plates five times.

Samples were taken by allowing the entire stream to flow into the sample bucket for a number of short intervals, uniformly spaced through the run. Samples were taken during the first, third and fifth runs, but since it soon appeared that there was little extraction in the first run samples were discontinued. The tests in the presence of impurities were run in the same way with the addition of 5 per cent of the injurious substance to the ore before adding the water.

The standard conditions used may, therefore, be briefly stated: 1. *Dilution*—8 lb. water to 1 lb. ore; 2. *Agitation*—by hand to a uniform thickness; 3. *Number of times over the plates*—five; 4. *Samples*—lip samples during the first, third and fifth runs: 5. *Impurities*—Five per cent added to the dry ore.

Description of the Tests

1. **Pure Mercury.** Five tests were run with plain mercury, two on pure ore, and one each with admixture of 5 per cent zinc sulphate, manganese sulphate and ferrous sulphate. All conformed to the standard conditions laid down. Of the two tests on plain mercury with pure ore, one was made at the beginning of the series and one at the end, and these gave closely concordant results. With the addition of the sulphates the plates coated badly, which without doubt accounts for the marked lowering of the extraction under these conditions.

2. **Sodium Amalgam.** The amalgamated plates were painted with 1 per cent sodium amalgam, which gave an exceedingly clean surface, and also by the slow evolution of hydrogen and formation of free alkali kept the plates free from coatings with pure ore.

However, under the influence of the sulphates there was still much tendency to coat. Four tests were run with this and with all the subsequent amalgams: one of pure ore and one with the addition of each of the three sulphates, in the order of zinc sulphate, manganese sulphate and lastly, ferrous sulphate.

3. **Tin Amalgam.** Tin amalgam formed a very bright, clean surface when painted on the amalgamated plates, and proved very resistant to coating by the sulphates.

4. **Lead Amalgam.** The lead amalgam formed a rough, somewhat gritty surface, with dirty, black spots on it that were very difficult to scrub off. However, it was scarcely tarnished at all by any of the sulphates, proving more resistant than any other amalgam tried. It seems possible that the slightly gritty surface aids in catching the gold particles and that this may explain the extraction obtained with the pure ore, which is higher than several amalgams giving an apparently better surface.

5. **Zinc Amalgam.** This amalgam formed a fairly good surface on the plates, but the extractions obtained were very poor throughout. It coated badly under the influence of the sulphates.

6. **Cadmium Amalgam.** The cadmium amalgam gave one of the best of appearing surfaces of any tried and remained quite clean and bright throughout the tests with the sulphates. Nevertheless, it gave one of the poorest sets of results of any in the series for reasons not at present apparent.

7. **Silver Amalgam.** This amalgam gave a good surface, but coated considerably with the sulphates. It was applied in the proportions recommended by Richards[7] by painting on after the plates were amalgamated with plain mercury.

8. **Gold Amalgam.** The gold amalgam of the consistency of thin paste was painted onto the plate in a similar manner to that used for the silver amalgam. It furnished a slightly gritty surface which showed a tendency to tarnish under the influence of the sulphates. The results were very disappointing, but the rise in the assay of the tailing with each succcessive run (see the tables) would seem to indicate the probability of salting from the gold used. If the assays of the first run (0.76 and 0.72) be taken, the extraction is as good as was obtained by sodium amalgam.

A total of 4.121 grams of gold were used and 1.699 were recovered on cleaning up the plates. The loss from gold remaining on the plates and carried off by the pulp stream was thus 58.9 per cent.

Tabulated Results

The results obtained by the assays of the tailings are recorded in ounces per ton in the following tables, the assays being in duplicate. The assay of the original ore was 2.49 oz. gold per ton.

TABLE No. 2
Ore with Addition of No Impurities

Amalgam	1st Run		3rd Run		5th Run		Extraction, Per Cent
Plain Hg	2.58	3.64	0.60	0.60	0.56	0.56	77.5
Plain Hg	...	...	...	...	0.64	0.56	76.3
Na Amal	3.30	3.30	1.46	0.72	0.72	0.76	70.2
Sn Amal	1.46	1.58	1.60	...	1.08	1.10	56.3
Pb Amal	2.56	1.82	0.80	0.80	0.80	0.78	68.7
Zn Amal	1.16	1.08	1.02	1.02	1.10	1.12	55.4
Cd Amal	1.14	1.14	1.36	1.50	1.48	1.36	43.0
Ag Amal	1.22	1.22	1.16	1.12	0.96	0.84	63.9
Au Amal	0.76	0.72	1.16	0.92	1.68	1.68	32.4

TABLE No. 3
Ore with 5 Per Cent of Zinc Sulphate

Amalgam	3rd Run		5th Run		Extraction, Per Cent
Plain Hg	1.18	1.16	1.08	1.16	55.2
Na Amal	0.84	0.82	1.46	1.44	41.8
Sn Amal	0.92	0.92	1.02	0.84	62.9
Pb Amal	1.12	1.14	1.12	1.10	55.4
Zn Amal	2.00	1.76	1.78	1.82	27.7
Cd Amal	1.10	1.12	1.46	1.48	41.0
Ag Amal	0.98	1.38	1.12	1.12	55.2
Au Amal	1.58	1.60	1.76	1.84	27.7

TABLE No. 4
Ore with 5 Per Cent of Manganese Sulphate

Amalgam	3rd Run		5th Run		Extraction, Per Cent
Plain Hg	0.76	0.76	1.40	1.44	43.0
Na Amal	1.54	1.52	1.04	1.38	51.4
Sn Amal	1.06	1.06	0.88	1.02	61.9
Pb Amal	1.04	1.36	0.98	1.04	59.5
Zn Amal	1.16	1.00	1.18	1.16	52.6
Cd Amal	1.20	1.20	1.50	1.44	40.8
Ag Amal	1.02	1.26	1.38	1.44	43.4
Au Amal	...	...	1.22	1.26	50.4

TABLE No. 5
Ore with 5 Per Cent Ferrous Sulphate

Amalgam	3rd Run		5th Run		Extraction, Per Cent
Plain Hg	1.46	1.46	1.30	1.52	43.4
Na Amal	1.98	1.96	1.12	1.12	52.2
Sn Amal	1.12	1.14	1.00	0.82	63.6
Pb Amal	1.80	1.72	0.86	0.84	65.9
Zn Amal	1.82	1.80	1.34	1.44	44.3
Cd Amal	1.66	1.28	1.18	1.18	52.6
Ag Amal	1.40	2.04	1.18	1.18	52.6
Au Amal	...	...	1.04	1.08	57.4

In order to compare the extraction made by the various amalgams, the percentages are tabulated in Table No. 6, placed in order of the efficiency of the amalgam with pure ore.

TABLE No. 6

Amalgam	Pure Ore	Ore & $ZnSO_4$	Ore & $MnSO_4$	Ore & $FeSO_4$
Plain Hg	76.9	55.2	43.0	43.4
Na Amal	70.2	41.8	51.4	55.2
Pb Amal	68.2	55.4	59.5	65.9
Ag Amal	63.9	55.2	43.4	52.6
Sn Amal	56.3	62.9	61.9	63.6
Zn Amal	55.4	27.7	52.6	44.3
Cd Amal	43.0	41.0	40.9	52.6
Au Amal	32.4	27.7	50.4	57.4

When the average extraction under all conditions is considered, the amalgams are placed as in Table No.

[7]Richards. Text Book on Ore Dressing. p. 115.

7. These figures are obtained by taking the average of the extractions obtained with a given amalgam when used with pure ore and in the presence of the three sulphates.

Table No. 7.

Amalgam.	Average Under All Conditions	Pure Ore	Ore and $ZnSO_4$	Ore and $MnSO_4$	Ore and $FeSO_4$
Pb Amal.	62.2	68.2	55.4	59.5	65.9
Sn Amal.	61.2	56.3	62.9	61.9	63.6
Plain Hg.	54.6	76.9	55.2	43.0	43.4
Na Amal.	54.6	70.2	41.8	51.4	55.2
Ag Amal.	53.8	63.9	55.2	43.4	52.6
Zn. Amal.	45.0	55.4	27.7	52.6	44.3
Cd Amal.	44.3	43.0	41.0	40.9	52.6
Au Amal.	41.9	32.4	27.7	50.4	57.4

To determine which of these interfering elements had the greatest effect in reducing the extraction, the mean of all different amalgams, when used with the same impurity was calculated. The percentage of the extraction compared with that obtained with pure ore was also determined, as set forth in Table No. 8.

Table No. 8.

Substance	Average Ext.	Per Cent. of Ext. with Pure Ore
Pure Ore	63.1*	100.0
Ferrous Sulphate	53.2	84.6
Manganese Sulphate	50.4	79.9
Zinc Sulphate.	46.8	74.2

*Gold amalgam values omitted as unreliable.

Conclusions

The results in Table 7 show that plain mercury excelled any of the amalgams in the treatment of a simple gold ore, when free from impurities. In the presence of sulphates, such as are frequently found in oxidized ores, the extraction was much reduced and plain mercury no longer gave the best results. With 5 per cent of zinc sulphate, plain mercury dropped to fourth place; with manganese sulphate, to seventh place; and with ferrous sulphate, to eighth place. When their average performance under all conditions was considered, lead and tin amalgams gave the best results with plain mercury third.

Table 8 shows the relative effect of the sulphates in lowering the extraction. Ferrous sulphate caused an average drop of 15.4 per cent; manganese sulphate, of 20.1 per cent; zinc sulphate, of 25.8 per cent. The injurious effect is due to the coating of the plates caused by the presence of the sulphates, and in general the amalgams which gave high extractions showed less tendency to coat than the others, as may be seen from the results in Table 7.

From the foregoing considerations, it appears that mercury has a greater affinity for gold when pure than when any other metal is amalgamated with it.[5] In these cases where an amalgam shows a higher extraction than mercury alone, the effect is not caused by any increased efficiency due to the presence of the foreign metal; but rather to the superior resistance of the amalgam to the effects of impurities.

In ability to remain bright and clean in the presence of sulphates we have confirmed Aaron's results so far as cadmium-amalgam is concerned, this heading the list; the other amalgams follow about in the order named: Lead, tin, gold, silver, sodium and zinc. Plain mercury was coated worst of all.

State College of Washington,
Pullman, Washington

An alloy of silver and cadmium is patented by Edward D. Gleason, of Flatbush, N. Y. It is characteristic of sterling silver, being ductile, durable, brilliant and resistant to oxidation. The composition is about 55 per cent silver and 45 per cent cadmium.

[5]Gold amalgam should probably be excepted from this statement owing to the unsatisfactory nature of the results obtained with it.

Metallurgical and Chemical Engineering in Great Britain

(From Our London Correspondent)

The General Situation

So far as scientific progress is concerned we are marking time. We do not feel any shame that the general level of papers read this winter before our technical and scientific societies is so poor. One cannot say with confidence that even the Iron and Steel Institute may not fall short of their past high standard in their meetings next month.

The blast furnace, steel foundry and the rolling mill have in one sense never been busier, but it is a business conducted by reduced staffs working at high pressure. Under these conditions the writing of papers becomes a burden which even the keenest are glad to leave aside. There is only the professional element—and that is reduced numbers now left to write papers.

When the war is over we shall pick up the pace again and research will appeal with a new zest. But just now, spare time, thought and talk is given to considerations of what will have to be done when the war is over, with reference to the organization of over-sea trade. Many little informal conferences have been held. Civilian manufacturers and ex-manufacturers in khaki, who have been able to leave their regiments for a few hours have fore-gathered. Difficulties have been frankly recognized, and on the whole the feeling may be described as one of cautious optimism.

The Sheffield Exhibition of German Cutlery

Your correspondent makes no apology for quoting in extenso the following two paragraphs from the Times Engineering Supplement of February 26, which he had overlooked in his last letter. They illustrate in regard for one industry alone some of the difficulties the recognition of which was mentioned above.

"The opportunities offered by the elimination of Germany's rivalry in the cutlery trade have been very effectively brought home to Sheffield manufacturers by the exhibition of a remarkable collection of German cutlery. The exhibition has been arranged by the Cutler's Company in co-operation with Mr. Walter Tyzack, head of one of the principal cutlery firms in Sheffield, who lent a collection from English agents who have been selling German products to export merchant houses and to retailers. The prices at which these goods had been sold are such as to show how formidable a task it will be for Sheffield manufacturers to secure the two million pounds worth of trade in cutlery which Germany has sacrificed by the war. There were pocket knives at 7½d. a dozen, large two-bladed penknives at 3d. and 4d each, champagne knives at 2s. 6. and 3s. 6d. a dozen, table knives at 1s. 5d. a dozen, safety razors from 3d. each, folding scissors at 1s. 7d. a dozen, and ordinary scissors at from 1s. a dozen. In many cases the prices of the finished articles are less than the bare cost of grinding in Sheffield, and the bulk of the specimens shown had been sold at about one-third or fourth the average price asked for Sheffield products of similar class. In quality and appearance the German goods were by no means to be despised; the workmanship was good and there was evidence of a strongly developed artistic instinct.

"To enable Sheffield makers to compete with such products some changes in methods, plant and working conditions of a revolutionary character would have to be made. Sheffield cutlers in the past have

by no means been so sympathetic towards the introduction of labor-saving machinery as were the Solingen operatives; but of late a much more reasonable spirit has prevailed and the exhibition—which was visited by crowds far in excess of the accommodation available—will serve to bring home to the workmen a better appreciation of the difficulties with which employers have had to contend in maintaining their businesses."

The War and the French Iron and Steel Industries

Although the invaded districts in France at present in German occupation is only 3.7 per cent of the area of France, it is largely industrial, containing before the war 8.2 per cent of the population. Prominent among the industries of the occupied area are those of iron and steel. The following percentages of the total French works are in the enemy's hands:

Iron pipe works	100	per cent
Iron mines	90	"
Pig iron	85.7	"
Iron girders	88.3	"
Coke	78.3	"
Cast steel	76.9	"
Steel rails	76.6	"
Steel ingots	76.0	"
Puddled steel	62.4	"
Iron plates	63.2	"
Iron wire	52.2	"

If in the progress of further conflict much injury is done to these districts France will be badly injured industrially.

The economic outlook in northern France and in Flanders is gloomy in the extreme.

Electric Steel-Making Furnace

The April issue of the Journal of the Institution of Electrical Engineers contains a paper read by Mr. T. D. Robertson before the Manchester local section of the I. E. E. with the above title. In its scope the paper was mainly historical and dealt with elementary principles of the Kjellin, Stassano, Heroult and Girod furnaces. The rest of the paper was given to a description of the "Electro-Metals" furnace of Grönwall, Lindblad and Stalhane. The description is characterized by an absence of data, unless the following particulars of the energy consumption of this furnace can be called data: "When melting cold scrap, using two slags and refining to a best quality, the approximate energy consumption decreases from 850 kw. hours per ton, in the case of a two-ton furnace to 750 kw. hours per ton in the case of a five-ton furnace. Those taking part in the discussion emphasized the need for figures apparently unaware that various papers read before the Iron and Steel Institute gave figures for other than the Electro-Metals furnace. It was in reply to this that the author gave some typical figures for the Electro-Metals furnace. For a 25 cwt. furnace producing 1406 tons a year about 850 kw. hours are estimated per ton. Taking electrical energy at 1 cent per kw. hour, and allowing for cost of raw material, labor, electrodes, repair and maintenance and raw material, the cost per ton works out at £6 5s. 6d. For a 2-ton furnace, producing 2250 tons per annum, about 800 kw. hours per ton are required.

Calculating on the same basis as before the cost per ton works out at £5 17s. 8d., and the 5-ton furnace producing 4050 tons per annum at 750 kw. hours per ton, works out at £5 11s. 3d. per ton. Management, laboratory and capital charges are not included in these prices.

The Institute of Metals

Absence from London at the time prevented your correspondent attending the March meeting of this Institute, and he has been dependant on the technical press for an account of what took place. Professor H. C. H. Carpenter of the Royal School of Mines presided. Perhaps the most interesting papers were those by Professor Huntington on "The Effects of Heat and Work on the Mechanical Properties of Metal," by Mr. S. Whyte on "The Micro-Chemistry of Corrosion," and by Professor A. A. Read and Mr. R. H. Greaves on "The Properties of Some Nickel-Aluminium and Copper-Nickel-Aluminium Alloys." In regard to the last two papers the common interest of corrosion phenomena linked them together, and it is in this connection that your correspondent would remark upon the apparent necessity for a revision and standardization of corrosion tests. While the index afforded by loss of weight through either direct chemical action or through local galvanized action on any test plate cannot be ignored, a better index and one more quickly ascertained is that of the determination of the e.m.f. (measured, of course, by a potentiometer) between the metal under test and those other metals with which it is likely to be used industrially. The electrolyte should always be the liquid with which the metal under test will come into contact.

Engineering Training

In the multitude of councillors there may or may not be wisdom, but of a certainty there will be difference of opinion. Over here we have sharply marked schools of thought as to how engineering education should be imparted, and in what proportions and in what sequence theoretical and practical training should be blended. The latest contribution to the consideration of this subject is Mr. A. P. Fleming's paper recently read before the Manchester section of the I. E. E. The author pointed out that "of the various plans of training for technical positions the following are the most common:

(a) By a trade apprenticeship combined with evening or part-time study. This method is particularly applicable to manufacturing.

(b) By a short period in works, then a college course, followed by works' apprenticeship. This plan is recommended by the Institution of Civil Engineers.

(c) By taking a complete college and then a works' course.

(d) By sandwiching college and works' training in varying periods.

(e) By taking a complete works' apprenticeship prior to technical training. This is not a satisfactory method for training for technical positions in manufacturing.

Of these plans, a, b and c are most suitable from the manufacturers point of view; but whichever method is adopted it is desirable that the practical training should terminate in the works, since a better opportunity is afforded to the student for obtaining permanent employment with the firm in which he has obtained his training. It is also most important that the entire training be preceded by thoroughly sound general education.

There is a wide diversity of opinion as to how long a period of practical training a technically educated man should have, and what its nature, should be. Some firms adhere to the five-year apprenticeship scheme as applying to all young men, whether they are being trained as workman or for technical positions, but the more modern tendency is to arrange a shortened course for the latter. While long practical experience is excellent it is not the mose effective

method of attaining the end in view. Moreover, a man who has had his intelligence developed by a technical college course should be able to acquire practical experience at a much quicker rate than one not so educated. The object is to afford an insight into manufacturing methods and economics, and to acquire a knowledge of how to handle men.

The author describes the methods employed by the British Westinghouse Co. at their works in Manchester in training their apprentices. The apprentice school method of instruction has been adopted. Instruction averaging about 5 hours per week is given during working hours to all "bound" apprentices, numbering about 300, in a school situated in the works. The regular rate of wages is paid during the time spent in study, and all the cost of books and stationery is borne by the firm. The teaching is done by twelve members of the firm's engineering staff, supplemented by lectures from the leading foreman and shop engineers, which deal specially with the trade subjects. The contact between the foreman and the apprentices in the school produces excellent results, and removes the diffidence which many of the apprentices feel in approaching the foreman with their difficulties. Where it is required to illustrate specal processes or describe particular apparatus, which cannot readily be done in the school by lantern projection or drawings, practical demonstrations are given in the works.

The most promising of the apprentices are selected for work in the testing departments and drawing office, and in other respects are allowed a wider range of work than that covered by their own trade. Each year about ten apprentices are selected as a result of their school work and shop progress and sent for one whole day each week to the course for engineering apprentics at the Manchester Municipal School of Technology. The cost of tuition, books, etc., is borne by the firm, and no deduction is made from the wages during the time spent at the school. Such youths are marked for advancement in the company's service as suitable opportunities occur.

Through their work in the school the interest of the foreman is aroused, and as a result increased attention is paid by them in the shops to the practical training of the apprentices.

This apprentice school has only been in operation for about a year, but so far the results both from the point of the company or of the apprentices are most encouraging.

It is early as yet to claim the method and routine employed by the British Westinghouse Co. as a final solution of the problem. For one thing under changing industrial, social and economic conditions there is no finality. Yet the problem before us is an insistent one. The old pride of handiwork and craftsmanship is disappearing, indeed has almost disappeared before the machine too and the factory system.

The pace at which industrial change takes place prevents our ever getting back to the old system and its intense pride of work. Yet some substitute must come. Not only do we do need it for the sake of those who rise by sheer force of character from the ranks, but it is obvious that the daily toil for daily bread of the bulk of our populations should have its intelligent interests and not lead to a mental atrophy of all brain power.

Electrolytic Corrosion of Gas and Water Mains

On the 23rd of February a paper was read before the Institution of Civil Engineers on "The Electrolytic Action of Return in Electric Tramways on Gas and Water Mains, and the Best Means of Providing Against Electrical Disturbances," by Mr. H. E. Yerbury. The author reviewed and criticised the Board of Trade Rules and Regulations and their revisions, from 1894 to the present date, and dealt with the influence of a leakage current on reinforced concrete. The preventive measures proposed by British and Continental authorities in order to reduce the potential differences between tramway tracks and pipes were classified, and a description of the function of a negative booster was given in detail. The author stated that where the rails and mass of earth were positive to pipes in the vicinity of the track there could be no danger to pipes in that area, as they were cathodic. On the other hand, danger existed to all pipes and metallic structures (where imbedded in soil) which were positive to the rails, as it was the flow of current out of the pipes that had a tendency to cause corrosion and pitting. The danger, however, was nothing like as great as would appear from a theoretical standpoint.

He pointed out that as current density and duration of current were the most important factors in connection with injurious electrolytic action on gas or water pipes, potential readings were misleading; it was well known that where a comparatively high difference of potential existed there was, as a rule, less injurious current passing. In his opinion the Board of Trade regulations in respect of leakage currents could easily be complied with on all tramway undertakings, and were absolutely effective in safeguarding the property of other authorities. Up to 600 volts could be allowed between overhead conductors and earth, and this increase of voltage would reduce the cost of feeders and also the heavy currents now dealt with.

Market Prices

(April, 1915)

Copper opened £69.10 and appreciated to the 12th, £72.12.6, then fell off slightly to £71.17.6 (13th), but recovered and continued rising to £76.12.6 (19th); was lower on the 20th (£75.17.6), but recovered to £77.12.6 on the 21st and was up to £81.5.0 on the 27th.

Tin opened £168, and was lower £166.10.0 on the 6th, recovering to £170.0.0 by the 8th. On the 9th it had eased to £168.10.0, but recovered and was £171 on the 13th. It then fell away to £164.10.0 on the 16th. On the 19th it had risen to £167.15, but was lower after to £164.10 on the 21st and the same price on the 27th.

Hematite opened 95/- and remained at this price throughout the month.

Scotch pig opened 73/9, and was 75/4½ on the 6th, then declining to 73/3 on the 8th. It recovered to 74/9 on the 12th, but was again down to 73/- on the 13th. Recovered a little 14th and 15th, but afterwards declined and was 70/6 on the 21st.

Cleveland opened 67/9 and was much harder on the 6th at 69/4½. It then declined to 67/3 (8th) and recovered to 68/9 (12th). Another falling off brought it to 67/- on the 13th, and after reaching 66/9 on the 16th, it dropped to 64/6 on the 21st, closing at 65½.

	£	s.	d.
Aluminium, ton lots	92	0	0
Alum lump, loose, ton	8	10	0
Antimony, black sulphide powder, ton	70	0	0
Borax, British refined crystal, cwt	1	3	0
Copper sulphate, ton	29	0	0
Caustic soda, 70 per cent ton	10	2	6
Hydrochloric acid, cwt	..	4	6
India rubber, Para, fine lb	..	2	4
Quicksilver (Spanish) bottle	12	1	3
Sal ammoniac, ton	49	0	0
Sulphate of ammonia, ton	13	12	6
Shellac, cwt	3	5	0
Platinum, oz., nominal	9	5	0
Zinc sulphite, cwt	..	8	0

Blast-Furnace Plant Auxiliaries and General Arrangement

BY J. E. JOHNSON, JR.

In addition to the apparatus previously described which is required for each furnace there must be a considerable amount of other equipment for the plant as a whole. Of course, it goes without saying that the enormous tonnages involved at modern blast furnaces can only be handled by first-class railroad track and equipment, both of cars and locomotives, and in sufficient amount, and that at practically all plants of any size cranes for handling heavy parts, cleaning up "messes," and doing innumerable kinds of work that was formerly done by hard manual labor, are extensively used. Very frequently they are arranged to operate grab buckets and magnets as well as serving for general utility cranes. These also are standard equipment and do not need to be specially described here.

The Water Supply System

The water supply system is one absolutely indispensable portion of the equipment which to judge by the location and the design of some plants was forgotten at the time of their construction and put in subsequently as an afterthought.

The modern furnace depends upon water-cooling for its very existence, not from minute to minute, but literally from second to second, since the tuyeres, coolers and cooling plates are exposed to the most intense heat and the severest conditions of scouring by iron and slag, not occasionally, but in many cases continuously, and only a thin surface of the highest possible conductivity cooled by a violent circulation of moderately cool water prevents their instant destruction.

For this purpose water in considerable quantity must be provided. Its quantity varies very greatly with the size of the furnace and the method of cooling adopted. Cooling plates require more than bosh jackets, and, of course, when cooling plates are used above the mantle they add their quota to the total requirements, since a certain minimum velocity must be maintained for each plate, the minimum depending upon the temperature to which the plate is exposed.

For an ordinary five hundred-ton furnace from 1200 to 2000 gallons of water per minute are required for cooling the tuyeres, hearth and bosh. In addition to this the water necessary for boiler feed, and very generally for condensers, must be supplied, and in modern practice great quantities are being used for gas washing also. This amounts to about 4 gals. for primary cleaning for every 100 cu. ft. of gas or about 2000 gals. per minute if all the gas is washed. It should be noted that the furnace cooling water can be and generally is used over for either condenser or gas cleaning. The consequence is that each blast furnace requires a very respectable volume of water, from 3,500,000 to 6,000,000 gallons per day, and a plant of several blast furnaces needs a supply which makes that of many large cities look small in comparison.

Plants have too often been designed with little or no consideration for their location in regard to water supply. There are perhaps more important considerations such as the arrangement of tracks, etc.—but in a number of cases that have fallen within my own experience a location close to the water supply would have been not only as good but better in other respects than the location actually chosen, at some distance from it, with the necessity of long lines of communication and long-distance supervision of the pumping plant, for, of course, in modern practice long suction pipes are rightly not tolerated, and the pumping plant must be close to the water supply and within a moderate distance above the water level. Moreover, the pumping plant must be able to run and supply water to the furnace irrespective of fluctuations in the height of the supply. These conditions are easy to fulfill if the plant be on the border of a lake or a stream whose level does not greatly fluctuate, but very difficult to meet in some cases where the source of the water supply is a stream with a rise and fall of many feet, such, for instance, as have the Monongahela and Ohio rivers in the Pittsburgh district.

The design of the pumping station must be based on the local conditions and on the size of the plant. Where a very large plant is needed on the banks of such a river it is often desirable, if not necessary, to sink a huge caisson down below low water level from a point high enough above the river level to be out of danger of floods, and run a tunnel of brick or concrete from this out into the river itself. This, of course, requires a cofferdam of some extent for the construction of the tunnel.

The pumps are located at the bottom of the caisson or pit and the flow of water into it is controlled by valves at the inner end of the tunnel so that no matter how high the river may rise the pumps cannot be drowned out.

The screening of the water is done in the pit, no attempt being made to erect screens over the mouth of the tunnel since they would be inaccessible in times of flood.

In other cases a masonry forebay is built at the bank of the river and extending well down below water level its front being entirely open to the river except that it is guarded by screens. These may either be fixed or arranged to be removed for cleaning. The latter, of course, can only be done by having two separate chambers both of which can be entirely cut off alternately, or by having two sets of screens, one in front of the other so that each one alternately can be raised for cleaning. The possible variations of these methods are of course almost infinite, but the question is one of great importance because the water supply of furnaces is more apt to be interrupted by floods than by any other kind of accident whatever. The likelihood of dangerously low water can be foreseen, and the necessary arrangements for an additional supply made in ample time, but when a flood arises, especially in a mountainous country, two or three hours may see a change from placid operation to one of absolute disorganization on account of water supply. This is for the reason that when these violent floods occur they pick up vast quantities of silt, leaves, and sticks, so that the consistency is almost like soup in extreme cases, and this combination can stop up a screen in a short time almost as effectively as could a plasterer, while owing to the location of the screens it is not always possible to clean sufficient of their area to let through the water necessary to the life of the plant.

Several years ago having occasion to provide a water supply for a small furnace near but not on the bank of a mountain river, subject to rises of some twenty or twenty-five feet, I installed a plant designed to meet these conditions which has been very successful in operation, and of which the principle may be useful to others. This plant was described in the April 18, 1914, issue of the *Engineering and Mining Journal*, from which the illustration of Fig. 1 is taken.

A forebay of brick-work was built with its base about two feet below the lowest water level, very much as in ordinary construction, but instead of screening this with a straight stationary screen a circular revolving screen was used, which was supported on trunnions built into the masonry. The outlets for the screened water were through the ends of the screen wheel and

the side walls of the forebay into the pump pits on each side of it, these suction pits being covered over with iron plates laid in cement so as to be water-tight even when submerged. The screen wheel fitted snugly between the walls of the forebay and was perfectly open in front. At the bottom it passed with bare clearance over a wide sill of concrete running clear across the forebay. At the top it was covered over with a curved plate which fitted down over the top segment of the wheel with small but sufficient clearance. The arms of the wheel were solid plates running from side to side the full width of the wheel, reinforced by angles

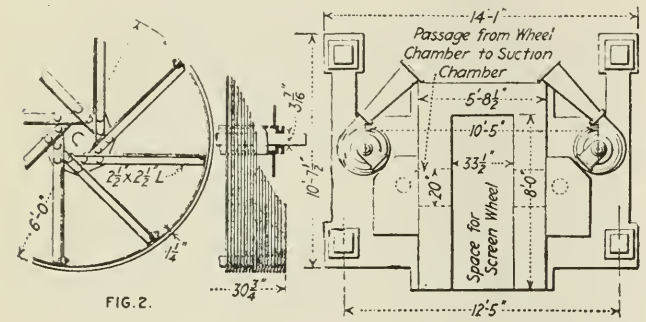


FIG. 2.

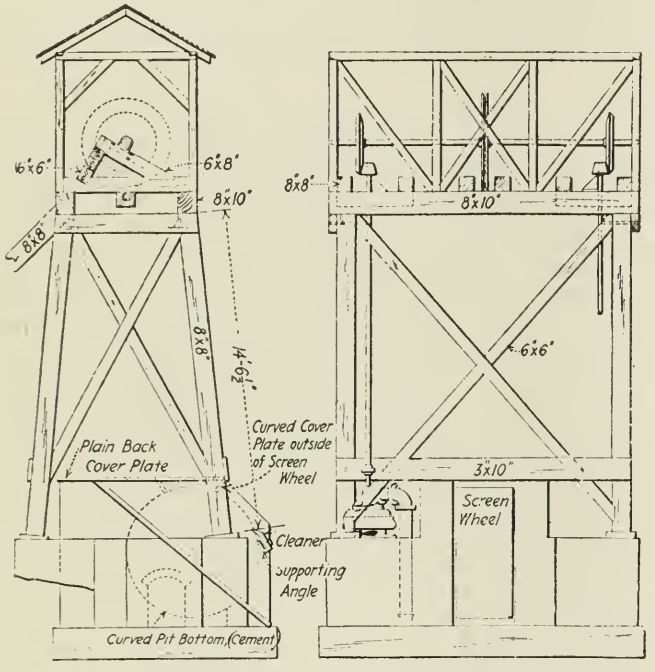


FIG. 1—SELF-CLEANING SCREEN FOR PUMP SUCTION

riveted to the hub as shown in the drawing. The sill and the curved cover plate at the top were a little wider than the space between two adjacent arms.

The wheel proper was made up of welded rings an inch and a half by a quarter, bent edgewise with half inch spaces between them. A stout angle across the front of the forebay carried cleaners which worked in the spaces between each pair of rings.

Supposing the pumps to be at work, and the water level somewhere about the center of the wheel, if the lower section of the screen through which the water is passing becomes obstructed by leaves, the pumps continuing to run, the level of the water inside the wheel is soon lowered well below that of the water outside, and this difference in level then works upon the arms of the wheel which thus virtually becomes an under-shot water wheel and rotates the obstructed section downward thus bringing a new clean section into play. When this becomes obstructed in turn the same action takes place and when the first section obstructed finally comes around to the cleaners, the leaves, etc., are thrown off by them and the wheel restored to a clean condition.

It will be noticed that centrifugal pumps with vertical shafts are used with their driving mechanism set on a platform many feet above the water level. The driving mechanism in this particular case was by wire rope and bevel gears, there being clutches to throw in or out either pump as desired. Now it would probably be preferable to use a vertical-shaft motor directly connected to the vertical pump shaft. A great advantage of the centrifugal pumps is that they have no valves to become obstructed, and can run submerged for an almost indefinite period. They are located about two feet above normal water level so as to make them easy of access for repairs, etc., under all ordinary conditions.

This plant had gone through several floods in which the screen wheel, pumps, and all were submerged for several feet, and has never failed, as far as I know, under those conditions.

A hand turning gear was provided to rotate the screen by hand if for any cause it should fail to work automatically, and of course it would be a very simple matter to arrange by a geared ratchet or some other mechanism to drive the screen wheel positively and continuously, which might be desirable in some cases.

This wheel was designed for a capacity of about one thousand gallons per minute, for which it was more than ample, and a plant of this kind with a capacity of many thousand gallons per minute could be built at a comparatively small expense. There is no patent on this design and any one is at liberty to use it who wishes to do so.

Pumping Machinery

Many different types of pumping machinery are used. For small plants and where steam economy is not important, and where the pump installation can receive attendance from the engine room force, direct acting steam pumps have often been used in the past, in fact, until quite recent years no other type of pumping apparatus was available except in the largest sizes. As a result different pumps were added from time to time and the number and variety of pumps to be found in the pumping station of some large blast furnace plants was remarkable.

The direct acting steam pump is moderately reliable, but not sufficiently so to run without attendance since the pumps may "stick on center," the valves may become blocked open, and various other contingencies may arise which necessitate inspection at frequent intervals. This type of pump is also extremely uneconomical. In the smaller sizes their steam consumption is probably always in excess of one hundred pounds of steam per horse power hour. In the larger sizes where compounding and triple expansion are used, and where more refinements can be included in the design, their steam consumption drops to the half of this and often to the quarter, the later figure being extremely rare except with what may be called pumping engines rather than steam pumps. In all the ordinary sizes steam consumption is probably never less than fifty to one hundred pounds per horse power hour.

For larger plants the vertical plunger pump with plungers directly connected to the cross-heads of a triple expansion engine, of the crank and fly-wheel type, with their cranks at one hundred and twenty degrees, are probably as economical as any type of pumping engine driven by steam machinery. They have the great advantage that being vertical the water cylinders can be placed near the normal water level, while the steam cylinders and driving mechanism are high enough

to be out of reach of any possible flood, and in case of a flood the pump cylinders may be submerged and continued to run indefinitely in that condition. These, of course, are necessarily large units and their speed of revolution is limited by the ability of the water to make its way through the valves and follow the plungers which, on account of the inertia of the water, is at a very slow rate. These pumps, therefore, seldom run at more than thirty revolutions, which makes their cost very high in proportion to their output.

In the last ten or twelve years the centrifugal pump with multiple stages has been developed to a high state of efficiency, and instead of being limited to thirty or forty feet lift as was the old single-stage centrifugal pump some twenty years ago, these pumps are now designed for lifts up to many hundred feet. Their efficiencies with good designs range from seventy per cent up to eighty in exceptional cases, and while this is considerably lower than the efficiency of a good plunger pump it is maintained through a long period of years.

The pumps are almost independent of leakage, operating solely by the velocity which their impellers impart to the water, and they are entirely valveless so that under any ordinary circumstances they will run without interruption for very long periods of time.

One word of caution may not be amiss here. The old centrifugal pumps were designed so that they would pass anything up to the size of cabbages, but the modern multiple stage pumps have what may be called a closed impeller with the outlets at its periphery rather narrow, so that sticks of moderately small sizes may lodge in these and cut off the water flow. For this reason screens must be provided with openings small enough to bar anything which could lodge in these discharge ports. The obstructions which will pass these ports are however larger than those which were likely to derange the valves of reciprocating pumps, and centrifugals have therefore the best of the argument in this very important respect. Owing to their extreme simplicity and to the fact that they have but one moving part, and to the entire absence of valves these pumps are relatively inexpensive, a result which is attained by virtue of the fact that they are run at very high speeds, and pass an enormous volume of water in proportion to their size.

I well remember that the master mechanic at the plant at which the pumping plant illustrated above, Fig. 1, was installed, assured me with great respect, but nevertheless with profound conviction, that those pumps would never deliver water enough to supply that furnace. When they were put into operation, however, one of them promptly ran away with the supply brought in by the race from the river, he had to bestir himself to increase the supply, and his doubts were overcome with a vengeance.

Centrifugal pumps on account of their extreme simplicity may be operated practically without supervision or at least only at several hour intervals, there being only a few oil cups to look after. These pumps may be driven by any type of motor desired but for large sizes there are practically only two to be considered. One is the electric motor, the other the steam turbine.

When the pumping plant is located at some distance from the main plant, electrical transmission is to be desired, as it will run for many hours without attention if properly installed and equipped, so that an occasional visit of an attendant is sufficient, whereas when steam machinery is employed it is virtually necessary to have an attendant on duty all the time though his work may be of the lightest 95 per cent of the time.

In small sizes the electric motor driven from an economical central station is probably more economical than the turbine, because the turbine economical in small sizes has not yet been developed, but in large sizes the directly connected turbine furnishes an ideal drive for these pumps. On account of the very high efficiency of the turbine, especially in view of the fact that a surface condenser may be installed in the water main and a very high vacuum attained without much expense, it is probable that the best type of unit of this kind is as economical in steam consumption as the vertical pumping engine earlier described because the greater efficiency of the turbine offsets the smaller efficiency of the pump, and the cost is only a fraction of that of the engine driven unit, so that where steam-driven plants are to be installed it may be expected that the turbine-driven centrifugal pump will play an increasingly important part.

In one plant of which I formerly had charge the pumping plant consisted of triplex plunger pumps belt driven from electric motors, and while the pumps were poorly designed and were too weak for the service for which they were furnished the combination formed (with this exception) a very satisfactory plant, and to my surprise the efficiency of the pumps was very high. A test was made of one of them using a large and accurate weir to measure the water, and although the pump was not tuned up for a test, but tested in its ordinary running condition, the efficiency of pump and motor figured out about 85 per cent, and undoubtedly a plant of triplex pumps properly designed and geared to their driving motors would be an effective and satisfactory type of pumping plant where electric drive was desirable, but of course this type of machine does not lend itself to satisfactory steam drive.

The details of these different types of pumping plants are no different from what they are in ordinary service and therefore need not be especially described and illustrated here.

Stand Pipes

The water supply is vital to the life of the furnace plant and must be continuous, since the failure of the water supply on the tuyeres for two seconds would almost certainly cause them to be burnt, and only a few seconds more would be necessary to burn the coolers and cooling plates as well. For this reason no amount of care expended to secure a reliable and constant water supply to the furnace is too great.

It is obvious that even with duplicate units in the pumping plant there must be an interruption of a few minutes from time to time in the supply, and it is therefore universal in good modern practice to have a stand-pipe with a capacity sufficient to take care of the furnace water supply for a limited period. What this period should be depends upon the judgment or, one might almost say, the individual caprice of the designer of the plant. I have seen some plants at which the stand-pipe looked hardly bigger than the smoke pipe of a domestic stove, while at many others it is of the size that would do credit to a large city.

It is probable that the stand-pipe should be sufficient to maintain a full supply of cooling water on all the furnaces for at least one hour. Then in case of a serious failure of the pumping plant the furnaces would be shut down and the water supply slacked to a very small percentage of its normal flow, and in this way they would be saved from injury for several hours. In case of necessity the tuyeres and even the coolers can be pulled if it is obvious that the water supply can not be restored before the stand-pipe gives out.

There are three types of stand-pipe in common use: first, the straight cylindrical pipe like a stack, second, the elevated tank (generally in modern practice having a spherical or parabolic bottom) supported on a steel

tower, and third, a flat tank of relatively small depth placed on top of some building for which it acts as a roof.

The first type is the poorest for the reason that only the upper third of it is useful for storage since when the water falls below that level the head is insufficient to maintain a proper supply. Or if the tank is built so high that a greater proportion is available then the water must be pumped much higher than is necessary to obtain the desired amount of storage, with consequent waste of power and high cost of equipment.

The second type is that which is commonly used as the stand-pipe for cities if no hills are available, and for large plants. The tank is elevated to such a level that its whole contents are available for a water supply, and the excess of the maximum over its minimum height of the water level in it is small so that not much excess pumping is required.

The third type is not so common now as it was a few years ago, but has much to recommend it, embodying as it does a very large storage with a very small fluctuation in height, and being supported on the walls of the building whose roof it forms, its expense is not excessive, although of course very heavy girders are required across the building to sustain its weight.

At some fortunate plants which receive their water supply by gravity little or no tank is used because of the slight probability of interruption to the regular water supply there being no machinery to fail.

Water Mains

The character of the water main, like that of many of the other auxiliaries, is determined primarily by the size of the plant. For small plants nothing but cast iron pipe is probably ever considered, but for larger plants riveted steel mains have sometimes been used, and it is possible that in the larger sizes they are cheaper for a given strength. One point should, however, always be kept in mind in designing mains, and that is that the water which is pumped through them varies from just above the freezing point to eighty or ninety degrees in some districts. The expansion therefore is considerable and means must be provided to take care of it. At one large furnace plant a large riveted steel main was pulled in two by contraction after being several years in service, and the job of making even a temporary repair was a very difficult one, while it could not be permanently repaired except by having the whole plant shut down, a condition which should not exist for many years at a stretch.

This illustrates a point which it is well to bear in mind in connection with auxiliaries, that while each furnace and its immediate accessories are shut down completely at periods ranging from one to three or four years the plant as a whole, even though it be not a very large one, is not likely to be shut down so completely as to permit stopping the auxiliaries for many years at a stretch. This fact should be borne in mind in laying out water mains, gas mains, electric lines, and sewer systems, particularly the first and last on account of their great size, their being buried underground, the great expense of doing anything with them, and the vast difficulty of rigging up temporaries to permit repairs to the regular ones.

Returning to the matter of the kind of pipe to be preferred, the cast iron has two very great advantages. The first is that cast iron is less subject to corrosive influences than any of the other ferrous metals, the extent to which it is eaten away being only a fraction of that at which steel is attacked under the same condition.

Second: A bell and socket cast iron pipe is laid with a lead joint every twelve feet, this lead being cast and calked to place on a backing of oakum in a way that makes it virtually an expansion joint, so that the expansion of each section is taken up at its ends. No heavy contraction stresses can arise in this kind of pipe, nor can any distortion due to cumulative expansion from one end.

Steel pipe, on the other hand, is rigidly fastened together in one piece, and if special precautions be not taken to prevent, the expansion or contraction is liable to be concentrated at one point and cause the failure of the pipe at that point. For this reason if steel pipe be used as a main water supply system, well-made expansion joints, preferably made on the principle of a huge stuffing box filled with oakum, hemp or other packing, and set up with a gland, should be inserted at such distances as to localize and limit the expansion and prevent its doing damage.

Where large plants are concerned, it is a matter for very serious consideration whether two mains should not be used instead of one, the two together being large enough to supply the whole plant, and one of them able to furnish an emergency or partial shut-down supply. By the introduction of a comparatively small number of duplicate valves permitting both mains to supply all parts of the plant, and at the same time enabling large sections of either to be cut out, provision can be made for repairs to these important accessories without much difficulty or expense, something virtually impossible when a single main is used.

Furnace Main Connections

The connections from the water main to the circulating system around the furnace are a matter of the greatest importance, and no amount of care, and no reasonable amount of money is too great to secure freedom from failure here.

It has been my misfortune to experience three partial failures of this kind, and while in every case we escaped without serious damage to the furnace, we were forced to desperate expedients, in one case being compelled to pull the tuyeres from the furnace as the emergency supply was insufficient to supply these as well as the coolers and cooling plates, the latter could not be removed without serious delay and so were left in and fed with the minimum quantity of water which would prevent boiling. In this way we managed to prevent the burning of any cooling member while we changed the fitting in the main supply line which had split but still remained in place, although its duration was evidently to be measured by minutes rather than hours.

It is my judgment that two independent supply lines should be used, equipped with the modern type of non-return valves close to the furnace main, these valves being bronze fitted throughout so as to prevent sticking in the hour of need. These supply lines should be of moderate size so that normally some water would flow through each and keep them both active, while in case of trouble with one the other would deliver an emergency supply. The non-return valves in case of breakage would prevent the water delivered by the unbroken main from flowing back out through the one which failed and is an indispensable feature of such a design.

Waste Water System

Until within recent years all the water used by the furnace was returned to the sewer supply so little polluted that it required no special treatment, the water having been used almost exclusively for cooling and condensing purposes, but this is no longer true since the introduction of the gas washer. The wet scrubbing of gas requires a large quantity of water both for cooling and cleaning purposes, and the water discharged from these systems is exceedingly foul, containing the dust from the gas, and also much of the fume which we

have been accustomed to consider separate from the dust. In most cases to return this foul water by way of the sewer system to the source of supply would be to invite legal action, and it must accordingly be settled so as to remove the greater proportion of its suspended matter. Even after giving it careful settlement it is still quite foul and should not be turned into the main sewer system without careful examination to see that it will not cause the filling up of the latter either by precipitation of suspended material, or by the formation of a deposit of dissolved matter upon the sewer walls.

Where very large quantities of waste water are to be handled brick or concrete sewers are used practically the same as in regular city sewer work, but the branches from these or the main sewer at smaller plants may be of different material. Generally terra cotta pipe is used from about two feet in diameter down, but in many cases square wooden boxes of heavy plank, strongly spiked together, are used very satisfactorily since they are relatively inexpensive and are very durable if located so that they stay wet all the time and are not liable to be broken by light shocks and heat, as are terra cotta sewers. It is probably safe to say that in nine cases out of ten the sewer system does not receive as much attention in the designing of plants as it probably should, and is put in as an afterthought, with the result of costing more, and not improbably being worse located than it might have been had it received earlier consideration. Above all, consideration should be given to design small sewers so they can be cleaned by punching without digging them up.

In many cases also where terra-cotta is used for secondary permanent sewers it is probable that the greater strength and durability of cast iron pipe of light section would more than justify its increased cost, since difficulties with a sewer, while they are not very frequent, are inconvenient and expensive to the last degree. Some miserable sewer buried under the ground and never thought of once a year, whose failure to carry off the waste water results in flooding everything, may necessitate the shutting down of the plant for hours in order to cut off or reduce the flow of water.

One point in the design of the sewer system relative to the plant as a whole is worthy of note. In plants located in northern climates much trouble is sometimes experienced from anchor ice forming on the screen below the water level and shutting off the supply of water. The main waste sewer is normally located to discharge below the pump intake, as is absolutely right and proper, but where this discharge consists of practically clean water which has been used only for cooling purposes the sewer may well be provided with an auxiliary discharge just above the main intake screen of the pumping plant, whereby some of the warm water returning may be discharged at the river bank so as to warm the entering water a little above the freezing point and so serve to cut off or prevent the formation of anchor ice with all its attendant annoyances. These are minor points in the consideration of the blast furnace plant as a whole, but they are apt to be extremely expensive ones unless given careful thought in advance.

Compressed Air Supply

In former times before electricity had reached its present state of development a supply of compressd air was one of the greatest conveniences that could be installed at a furnace plant. It was very frequently used for operating bell cylinders, for drilling the tapping hole, for operating pneumatic tools on repair jobs, and many simliar operations. For this purpose an air compressor of good design was installed in the power plant, and the air piped to the points of utilization. In good practice branches with valves were inserted in the main at different points so that air could be taken wherever it might be needed, with a short temporary line or hose.

The modern designs of air compressors are greatly improved over those of a few years ago, being more economical and more reliable, and air supplies a very desirable form of power, being absolutely safe and extremely convenient. Especially for repair and construction work no substitute for the compressed air riveter and other tools of that kind has as yet been discovered. Where compressed air plants are installed as a permanency an after cooler should always be provided to cool the air to or below the temperature of the atmosphere just outside the power house so that the moisture condensed out of the air by compression may be removed at that point and not go through the line as vapor to condense in some distant pocket where it can make trouble in Winter by freezing up.

Many types of compressors have been brought out, and one known as the straight line type, which is of the same general design as the long cross head blowing engine, but laid horizontally, has had considerable popularity, but compressors are very uneconomical unless they are compounded as to both steam and air. This means two cylinders for each, and therefore the straight line type must have four cylinders all in a line to embody these features. This makes a rather complicated and extremely inaccessible type of apparatus, and as this type of engine has two cranks and two connecting rods virtually no more machinery is involved to make a cross compound, two-stage tandem apparatus of it, with the advantage of vastly greater accessibility and generally a more economical design. The space required, and the foundation cost are greater with the cross compound type, but its operating advantages are well worth the difference.

Electric Supply

There are still a few furnace plants in existence which are without an electric supply, and are lit at night by oil torches, colloquially known by the descriptive name of "smoke pots," whose light is extremely poor and inconvenience very great, but within a few years the furnace which does not have an electric plant at least for lighting purposes will be a thing of the past. On practically all modern plants so much of the work is done by electricity that an electric plant of considerable size must be provided. In many cases the electric stock hoist is used, electric bell hoist, pumping plants, lights, and many other minor but necessary operations of the furnace are conducted by electricity.

Where the furnace plant is in conjunction with steel works the electric plant of the combined works becomes enormous. That at a steel works of two or three thousand tons daily capacity is probably as large as that of the average city of half a million people. The electric plant for the blast furnace does not differ essentially from electric plants for other uses and must be designed primarily with reference to its size and the service to be expected of it, never forgetting that on account of its convenience other duties will be hung on to it from time to time, and that the plant which does not start with a hundred per cent reserve capacity will probably soon be too small to do what is required of it.

Where very large electric plants are to be installed it is still a question as to whether the gas engine or the steam turbine is the more economical. The gas engine is undoubtedly the more economical by twenty-five to thirty-three per cent on the heat unit basis, but its operating cost is decidedly higher, and its fixed charges are very much greater than those of the steam turbine. It is therefore very largely a matter of local conditions.

If coal be high, intelligent labor plentiful, and capital not too dear, the gas engine is to be preferred. When these conditions are reversed undoubtedly the steam turbine is the best. The intermediate conditions must be decided on their merits after careful examination of all the factors.

The steam turbine has one great advantage in that it may be used as a low pressure machine exclusively, and in two of the most modern plants which combine both blast furnaces and steel works the blowing engines are steam driven, and exhaust their steam about at atmospheric pressure into turbines which drive the electric generators. The turbine is by far the most economical motor in existence for low pressures, while it is inferior to the piston engine at higher pressures. This arrangement places each type of machine under the conditions for which it is best adapted, and makes a type of plant which has everything to commend it when the electrical requirements are sufficient to use up the steam from the blowing engines.

In smaller sizes the electrical plant may be either steam engine or turbine driven, the steam engine probably being preferable in small sizes and the turbine having an increasing advantage as the size of the plant increases.

VOLTAGE AND KIND OF CURRENT TO BE SELECTED

The voltage and kind of current, direct or alternating to be preferred depends on the local conditions. For small plants two hundred and twenty volt direct current gives excellent satisfaction. This voltage is high enough to keep the cost of copper in transmission lines within reason, and is low enough to give good service with incandescent lamps, while for electrical machinery which requires much control, such as cranes, ore bridges, and the like, direct current still seems to have the advantage over the alternating on account of the ease of reversal, the possibilities of dynamic breaking, etc. At large plants where the power is transmitted in great quantities the direct current is out of the question except as an auxiliary. The alternating current must be used so that it may be stepped up to any voltage desired for transmission and stepped down at the point of utilization. If direct current be required for crane service or the like, it is produced by motor generator sets or rotary converters. When alternating current is used different voltages may be used in different services to suit the individual conditions. For mill motors and the like where men are likely to come in close contact with them four hundred and forty volts or less are used, whereas on large motors such as those which drive rolling mills direct, voltages from twenty-two hundred up to sixty-six hundred are used.

(To be concluded in July issue.)

Messrs. **Eimer & Amend**, Eighteenth Street and Third Avenue, New York City, have issued their catalog M on Apparatus for Metallography, describing the Wysor combined grinding and polishing machine and optical metallographic apparatus.

Ulcoloy is a new copper-lead alloy made by the United Lead Co., 111 Broadway, New York City. While ordinary copper-lead alloy under usual conditions cannot be cast without a crystallization of copper long before the lead hardens, ulcoloy is made by a patented process in such a way as to hold the copper uniformly distributed throughout the mass until it cools and hardens. The chief applications of ulcoloy are as a bearing metal, as a metallic packing and for bronzes and castings. As an acid-resisting alloy it is especially suitable for acid valves and pumps where polluted or acid waters come in contact with it.

The Chemical Industries of Germany[1]

BY PROF. PERCY F. FRANKLAND, F.R.S.

It is remarkable that the Royal House of Prussia has during many centuries been associated in one way or another with chemical enterprises of various kinds. Thus already the second ruler of the country, the Markgraf John (1608-1619) was actually surnamed "the Alchemist" in consequence of the zeal with which during many years he pursued his investigations on the transmutation of metals, whilst a number of his successors exhibited great interest in the same problem—the manufacture of gold—which has never failed to fascinate the needy princes—and what princes are *not* needy?—of all ages and all nations.

The Great Elector (1640-1688), who did so much to advance the power of Prussia, was a patron of chemistry, which was just then beginning to emerge, as an experimental science from the obscurantism of alchemy. He provided the celebrated Kunkel with a laboratory and glass furnaces on an island in his park at Potsdam, and it was there then in 1678 Kunkel made the discovery of ruby glass, produced by means of traces of gold, and which is still an unsurpassed method of coloring glass for ornamental purposes. Kunkel also rediscovered phosphorus, which has previously, in 1669, been obtained by the alchemist Brand of Hamburg, who had quite accidently produced it in the course of his attempts to extract the Philosopher's Stone out of urine.

But while the discovery of yellow phosphorus is thus of German origin, its production on an industrial scale was, until twenty years ago, only carried on in England and France. In 1892, the manufacture of phosphorus by electrothermic means was introduced into Germany by the Chem. Fab. Griesheim-Elektron at Frankfort.[2] Red phosphorus was discovered by Schrötter, an Austrian chemist, in 1848, and was adapted for safety-matches by the German Böttger in the same year. His invention was first taken up in Sweden, and was not adopted until ten years later in Germany.

The match industry has assumed its largest dimensions in Germany. Thus the German annual production in 1912 was $23,000,000.[3] The value of all matches (British and foreign) consumed in Great Britain in 1910 is estimated at $6,468,750—about nine matches per day per head. Messrs. Bryant and May's (by far the largest English concern) turned out 1,152,000,000 boxes in 1907. This represents about one-half the British output. In 1907 the total value of British production was $3,875,000, of which $380,000 worth was exported.[4] The British export of matches is diminishing. It is worthy of note that Japan in 1901 exported matches to the value of $6,000,000.

PORCELAIN

Another great German industry owes its origin to alchemistic studies made by Böttcher in the reign following that of the Great Elector, namely, that of Frederick III. (1688-1713), first King of Prussia. Having succeeded in making gold before witnesses, Böttcher was seized by order of the Elector of Saxony and was "interned" at Dresden, where, although he did not succeed in making the much-desired gold, he founded along with the physicist Tschirnhaus, the celebrated Dresden porcelain industry.

The astute Frederick the Great (1740-1786) was

---

[1] A paper read before the Birmingham section of the Society of Chemical Industry, on March 4, 1915.

[2] The author has much pleasure in acknowledging the assistance he has received from the valuable compilation by Professor Lepsius of Berlin, "Deutschlands Chem. Industrie 1888-1913," and from that by Dr. Duisberg, of Elberfeld, "Wissenchaft und Technik," 1911.

[3] Molinari, "General and Industrial Inorganic Chemistry," 1912.

[4] Clayton.

anxious to manufacture the Dresden ware at Berlin and to this end commissioned his court apothecary, Johann Heinrich Pott, to institute investigations. These attempts were, however, all unsuccessful.

The great Frederick placed much faith in secret agents and it was by means of spies that he succeeded in discovering the secrets of the Dresden porcelain manufacture, for at his instigation an enterprising merchant, bearing the name of Gotzkowski, with the assistance of a Saxon workman, brought the secrets of the Dresden process to Berlin and established a porcelain factory in the Leipziger Strasse, which still remains the warehouse for the Berlin porcelain goods. But Frederick later stopped the pecuniary assistance with which the factory had been subsidized, and Gotzkowski was forced to sell the concern of Frederick for about $150,000, and so was established the celebrated Berlin Royal Porcelain Factory, amongst the products of which are the well-known crucibles and evaporating basins. The flourishing state of the Germain porcelain and pottery manufacture is attested by the fact that during the past twenty-five years the number of works has increased from 228 to 359, and the number of workpeople employed from 37,000 to 66,000. In 1912 the German exports of china, earthen and stoneware were valued at upwards of $17,500,000.

GLASS

Even still more important is Germany's glass manufacture, for which she has long been pre-eminent. The annual export in recent years has been over $35,000,000.

CYANIDE INDUSTRY

In the early eighteenth century an accidental discovery was made by Diesbach, a Berlin color-maker, which has proved of great industrial importance. Diesbach was preparing what is known as Florentine lake, a red pigment obtained by precipitating a solution containing cochineal extract and an iron salt with caustic potash. It so happened, however, that the potash used by Diesbach had been in contact with bone-oil containing some cyanide, and the result was that, instead of the result he anticipated, a magnificent blue coloring matter was obtained. This substance, which is still known as Berlin or Prussian blue, was the first cyanogen compound to be discovered.

The cyanogen compounds have played a most conspicuous part in the development of organic chemistry, and every source of cyanogen has been exploited for obtaining them. In recent years the demand has increased enormously owing to the employment of sodium and potassium cyanides in the extraction of gold. To meet this demand a number of synthetical methods for their preparation have been super-added.

Germany's annual production of cyanides is estimated at 10,000 tons, valued at $3,250,000, or about half of the world's production.

BEET-SUGAR INDUSTRY

Another industry, also had its beginnings in the eighteenth century, during the reign of the Great Frederick, and was the outcome of the laborious researches of Marggraf (born in Berlin in 1700, and a pupil of Stahl) on the occurrence of sugar in the vegetable kingdom. Of the numerous plants investigated from this point of view he found that the beetroot (*Beta vulgaris*) contained the largest proportion of saccharine material and that the sweet-tasting substance was identical with that present in the tropical sugar cane (*Saccharum officinarum*).

It was not, however, until some fifty years later that the observations of Marggraf led to the first beet-sugar factory in the hands of Franz Karl Achard, who was subsidized in this venture by the Prussian King, Frederick William III (reign 1779-1840), who was also the founder of the University of Berlin.[5]

The beet-sugar industry had to contend with strenuous competition on the part of the cane-sugar manufacturers, who were chiefly English and who are said to have endeavored to corrupt Achard by heavy bribes. The industry was, however, greatly promoted when, in 1806, Napoleon issued his famous edict closing the European ports to British goods. The vast extent of this industry at the present time can be gathered from the following figures:

Total sugar crop for 1912-13: Cane sugar, 9,211,755 tons; beet sugar, European (one-third German), 8,310,000 tons; beet sugar, United States, 624,064 tons; total, 18,145,819 tons.

The sugar industry should give us food for serious reflection when we consider the following facts: United Kingdom spends annually $115,000,000 on 1,700,000 tons imported sugar. Germany produces $180,000,000 worth of beet sugar on 1,300,000 acres. France produces $65,000,000 on 570,000 acres; all continental countries together produce $580,000,000 on 6,000,000 acres.[6] In the United Kingdom there is only one small experimental beet-sugar factory in existence. The beet-sugar industry is of particular interest in connection with the present European crisis, inasmuch as it is a most notable example of an industry which largely owes its successful inception to a state of war which disturbed the previously established order of things in the matter of sugar supply.

In this country [Great Britain] agriculture is well known to be productive of a conservative frame of mind, but that it is not so in Germany is well illustrated by the extraordinary progress which has been made in the cultivation of the sugar beet under the guidance of systematic scientific research. Thus, in 1840, 100 kilograms of beet gave 5.9 kilograms of sugar; in 1850, 7.3; in 1870, 8.4; in 1890, 12.5, and in 1910, 15.8. In 1871 the mean production of beet per hectare[7] was 246 quintals,[8] and in 1910, 300 quintals. In 1867 the consumption of coal for 100 kilograms of beet was 35 kilograms; in 1877, 24; in 1890, 10, and in 1900, 7. Further economy in coal has been effected by means of the Kestner concentrator.[9]

SULPHURIC ACID, SODA AND BLEACHING POWDER INDUSTRIES

Sulphuric acid was discovered by the German alchemist Basil Valentine in the fifteenth century. The production of this fundamental acid, however, on any considerable scale took its origin in Birmingham, where Dr. Roebuck in 1746 introduced the classical leaden chamber process. At the beginning of the nineteenth century it became an industry of great importance, more especially in England, because of this acid being required for the manufacture of carbonate of soda by the Le Blanc process.

The manufacture of Le Blanc soda was taken up in England in 1814, especially in connection with soap-making, and it was in England that this manufacture assumed the largest proportions. The enormous ad-

[5]There was no University in Berlin until 1809, but the following figures will show how Prussia has made up for lost time in this respect. In 1913-14, there were 7613 male and 770 female matriculated students, and 4113 male and 89 female non-matriculated students. The annual income was $1,231,550, of which $1,023,250 came from the State, $204,500 from fees, etc., and $3,800 from other sources. The annual expenditure was $1,231,550, of which the teaching staff accounted for $523,950; departmental expenses, $500,700; building expenses, $53,050; reserve, $33,400; administration, bursaries, etc., $120,450. ("Minerva," 1914.)

[6]C. W. Fielding, "Morning Post," Jan. 23, 1915.

[7]Hectare = 2.5 acres.

[8]Quintal = 100 kilograms.

[9]Molinari, "General and Industrial Org. Chem.," 1913.

vances made in this manufacture during the past century may be gathered from the fact that the price of carbonate of soda in 1818 was about $210 per ton, while to-day it is only about one-tenth of that amount. One of the determining factors which made England the principal home of soda manufacture was the great development of the English cotton industry during the nineteenth century.

During a large part of the last century England manufactured Le Blanc soda, sulphuric acid and bleaching powder[10] for most of the world. But during the latter half of the century the rival ammonia soda process made its appearance. The original discovery of the reaction on which it depends—it was first patented in England by Dyar and Hemming in 1838—is ascribed to several different persons, but the process was first made an industrial success in Belgium by M. Ernest Solvay. The Couillet works were founded with a capital of about $30,000 in 1863; the numerous affiliated works are now to be found in Belgium, England (Brunner, Mond and Company), Germany, France, Italy, Spain, Austria-Hungary, Russia and North America. They employ 35,000 persons. During the fifty years the price of soda has been reduced from $80 to $20 a ton. The displacement of Le Blanc soda by ammonia-soda involved the introduction of new methods of chlorine manufacture. After numerous abortive attempts in various directions, the successful production of electrolytic chlorine has been achieved, and about half of the bleaching powder in the world is now made by this means.

Electrolytic chlorine is now often converted into liquid chlorine (12 cents a kilogram), of which large quantities are used at Stassfurth for the annual preparation of 500,000 kilograms of bromine, and the Badische Anilin und Soda Fabrik used in 1900 more than 1,000,000 kilograms for the preparation of chloracetic acid employed in the manufacture of synthetic indigo.

In the manufacture of sulphuric acid, again, the old-fashioned English or leaden chamber process has not been allowed to remain unchallenged, for since the beginning of the present century it has had to meet the competition of the so-called contact process. This is based on a long known reaction,[11] which, however, remained almost unutilized until the meticulous industry of German chemists and the courageous enterprise of German manufacturers developed it into a commercially successful process, which was elaborated in the works of the Badische Anilin und Soda Fabrik at Ludwigshafen.

The ammonia-soda and the contact sulphuric acid[12] processes, although carried out in England, have been largely instrumental in making other countries, more especially Germany and the United States, independently of the English production of these all-important chemicals.

In 1882 the world's consumption of soda was 700,000 tons (160,000 ammonia-soda), and in 1902, 1,760,000 tons (250,000 Le Blanc). In England, in 1876, $35,000,000 was invested in the industry, which gave employment to 22,000 workpeople. In 1880 the British output was 430,000 tons, and in 1896 it was 800,000 tons. North America in 1886 produced 1100 tons, and 300,000 tons in 1898; and Germany in 1878 made 42,000 tons, 300,000 tons in 1901 and 400,000 tons in 1910.[13] The first soda works in Germany was only erected in 1843 by Hermann at Schönebeck, near Magdeburg, and the first leaden chamber by Kunheim in 1844 on the Tempelhof Plain near Berlin. (See also the statistics in Table I.)

[10] Discovered by Tennant in 1799.

[11] This reaction had for many years been used by Messel in England, but only for the manufacture of SO_3.

[12] The Clayton Aniline Co. and Nobel's Explosive Works have contact sulphuric acid plant.

[13] Molinari.

HYDROGEN INDUSTRY

The electrolytic production of soda and chlorine is, of course, attended with the evolution of enormous volumes of hydrogen. At first this gas was allowed to go to waste, but gradually interesting and important uses have been found for it.

1. Dirigible balloons have been rendered possible by taking advantage of the lightness of the internal combustion engine. One horse-power engines are but little heavier than 1 kilogram. Twenty-seven thousand cubic meters of hydrogen is required for a modern airship. The balloon sheds are often established near electrolytic soda works, or the gas may be transported in steel cylinders compressed to 150 atmospheres. Five hundred cylinders containing 2750 cu. m. of gas are placed on one railway wagon and more than eight such wagon loads are required for the filling of a single Zeppelin.

2. Autogenous welding with oxyhydrogen flame, a most important application of hydrogen, was introduced at the beginning of this century by the Chemische Fabrik Griesheim-Elektron. The oxy-acetylene flame is now more commonly used.

3. Artificial gems are made by means of oxy-hydrogen flame. Some thirty years ago C. V. Boys succeeded in fusing quartz with the oxyhydrogen flame and then drawing it out into incredibly thin fibers, which have proved of the highest value for certain physical experiments of extraordinary delicacy. The same source of heat was much later, in the nineties, employed by the French investigator, Michaud, to reconstruct rubies from small fragments of this gem. At the beginning of this century Verneuil and Paquier, in Paris, succeeded in making synthetic rubies. A little later Wild, Miethe and Lehmann in Germany elaborated methods for producing synthetic corundum, rubies, amethysts and sapphires, which are manufactured by the Elektrochemische Werke at Bitterfeld. These products are identical in chemical composition and physical properties with the natural gems, and the rarest varieties of these can be obtained at will. Fused alumina (very pure) gives corundum; fused alumina + 2½ per cent chromic oxide gives ruby; fused alumina + magnesia and titanium oxide and ferric oxide gives blue sapphire. These synthetic gems are now manufactured to the extent of about 6,000,000 carats annually (1 carat = 0.205 gram), or 1230 kilograms or more than 1 ton. Experienced connoisseurs can, however, distinguish between the natural and artificial gems, with the result that the former have not diminished in value. Natural rubies or sapphires of 2-4 carats cost $100 to $250, and larger stones up to $750, while the artificial would only cost 1/500 to 1/1000 of those amounts.

A still more recent and much more important application of hydrogen is for the hardening of fats, which depends on the transformation of unsaturated into saturated acids by means of hydrogen in the presence of a catalyst (nickel, palladium, etc.).

INDUSTRIES CONNECTED WITH ARTIFICIAL ILLUMINATION

The world is greatly indebted to Germany for inventions which have largely revolutionized artificial illumination, firstly, in connection with gas and more recently in respect of electric lighting.

Thus, one of the most remarkable discoveries in this domain was that of incandescent gas lighting, which was made by the Austrian Count, Dr. Carl Auer v. Welsbach of Rastersfeld in Styria, as the result of lengthy, laborious and ingenious researches. The now

TABLE I—PRODUCTION IN TONS, 1910*

	Germany	England	France	United States	Europe	World
Sulphuric acid (H_2SO_4)	1,250,000	1,000,000	500,000	1,200,000	3,700,000	5,000,000
(of this by contact process)	400,000	.....	.....	250,000	.....	.....
Soda	400,000	700,000	200,000	250,000	.....	2,000,000
(of this Le Blanc soda)	30,000	120,000	.....	.....	.....	150,000
Saltpetre consumption	786,000	93,000	337,000	523,000	1,740,000	2,360,000
(of this for nitric acid)	150,000	.....	.....	50,000	.....	.....
Hydrochloric acid (30 per cent)	450,000	**	.....	.....	.....	.....
Bleaching powder	100,000	....	.....	.....	.....	300,000
(of this electrolytic)	70,000	.....	.....	.....	.....	150,000

*Duisberg, "Wissenschaft und Technik," 1911.
**Already in 1895 the estimated production of hydrochloric acid in England was 1 million tons, and for the whole of Europe 2 million tons (Molinari).

so familiar gas-mantles are prepared by the ignition on the cotton frame of a mixture of 99 per cent of thorium nitrate and 1 per cent of cerium nitrate.

The source of these rare earths is monazite sand, the elaboration of which has become a very important industry depending on fractional crystallization, which already many years ago was brought to such a high pitch of perfection in the laboratory of Sir William Crookes. Out of this monazite sand Hahn in 1910 succeeded in extracting mesothorium and the process is carried out on a large scale at the works of Dr. O. Knöfler and Company at Plötzensee near Berlin. Radium bromide is worth about $85 a milligram, mesothorium about $37.50 a milligram. The mesothorium is only present in the monazite sand in extremely small proportion, about one part in 150,000,000 parts of the mineral.

I may also refer to Auer-metal, a preparation of iron (Fe 30 per cent) containing cerium, which sparks when scratched with hard steel, and which is familiar as a substitute for matches.

Another outlet for the use of hydrogen has been in reducing the rare metals osmium (melting point 2500 deg. C.), tantalum (melting point 2300 deg. C.) and tungsten (melting point 2850 deg. C.).

In 1903 the Auer Company showed that the carbon filament of electric incandescent lamps could be replaced by an osmium filament, with an economy of 50 to 60 per cent of current. In 1905, Siemens und Halske showed that a tantalum filament was cheaper and more advantageous, and in 1906 that the tungsten filament was even still better. Tungsten occurs in sufficient quantity in nature as wolframite (iron tungstate) and scheelite (calcium tungstate) to enable the metal to be now sold as filament-metal for $1.50 to $1.75 a kilogram.

Some idea of the enormous and increasing scale on which the incandescent lamp manufacture is carried on in Germany may be gathered from the figures in Table II.

TABLE II—PRODUCTION IN GERMANY

	1911	1912
Metallic-filament electric lamps	47,211,892 pieces	76,185,721 pieces
Carbon-filament electric lamps	24,791,196 pieces	20,975,348 pieces
Incandescent gas mantles	126,050,954 pieces	135,320,173 pieces
Arc-lamp carbons	10,740,025 kilos.	11,093,154 kilos.

According to V. B. Lewes, the consumption of gas-mantles in 1912 was: Germany, 100,000,000; America, 60,000,000; England, 38,000,000; France, 16,000,000; Belgium, 3,500,000; Italy, 3,000,000; Russia, 1,500,000.

The special tax imposed in Germany on lighting apparatus realized from the above sources in 1912 was $4,000,000.

AMMONIA

Of the commoner inorganic chemicals which are produced on the largest scale, one of the most important is ammonia, which has for so many years been obtained as a byproduct in the manufacture of coal gas.

So backward was this industry in Germany, that actually even as late as 1874 the ammoniacal liquor from their gas works was run to waste. All the more remarkable is the state of affairs to-day as betrayed by the following figures. The world production of ammonium sulphate was 210,000 tons in 1890, 500,000 tons in 1900, and 1,330,000 tons in 1912. Germany's production of ammonium sulphate in 1912 was about 370,000 tons.

The principal use of sulphate of ammonia is as a nitrogenous manure, as which it competes with Chili saltpeter; they may be taken as of equal money value per unit of nitrogen. In this connection Germany's manure bill, given in Table III., is interesting.

TABLE III—GERMANY'S MANURE CONSUMPTION

	1888 Tons	1912 Tons
Chili saltpeter*	225,000	650,000
Sulphate of ammonia	50,000	500,000
Superphosphate	250,000	1,800,000
Basic slag	250,000	2,200,000
Crude potash salts	160,000	3,000,000
Lime	500,000	800,000
Other manures		500,000
Total value		$150,000,000

*The total import of Chili saltpeter into Germany in 1912 was 800,000 tons, of which only 150,000 tons was used for manufacture of potassium nitrate and nitric acid.

It is the ambition of the Germans, firstly, to make themselves independent of the industrial products of other countries, and secondly, to produce in excess of their own needs and to impose this surplus on the rest of the world. Thus, they pride themselves on displacing more and more of the foreign Chili saltpeter by home-made sulphate of ammonia, and in 1911 they used in agriculture 75,000 tons of ammoniacal nitrogen against 70,400 tons of foreign saltpeter-nitrogen. This partial success they look forward to making complete and decisive by developing new methods of producing ammoniacal nitrogen and nitrates which can be carried out in Germany.

Of such methods there are already two in operation, and they are associated with that great problem which confronts mankind as a whole. How to supply the combined nitrogen, which will be necessary to build up the food-stuffs for the teeming millions of the future, after the deposits of Chili saltpeter are exhausted? This is the same problem as that of fixing the nitrogen of the air, which long ago, before anything was known of nitrogen at all, man had solved empirically by growing leguminous plants in the rotation of his crops, thereby increasing the fertility of the soil, although the mechanism of this time-honored procedure was only experimentally demonstrated in the last decades of the 19th century by the German investigators, Willfahrt, Hellriegel and Nobbe.

FIXATION OF ATMOSPHERIC NITROGEN BY INORGANIC MEANS

1. This has been successfully accomplished by the Birkeland and Eyde electric furnace, and the Schönherr electric furnace of the Badische Anilin und Soda Fabrik. These are simply realizations on the industrial scale of laboratory experiments made by Cavendish 130 years previously. This method is applicable only in Norway or other countries where abundance of water power renders the production of cheap electrical energy possible. It is being carried on by an international com-

pany at Notodden in Norway. They propose to use 300,000 horse-power capable of yielding 150,000 tons lime-saltpeter (15-20 per cent N) or about one-twelfth of the total amount of Chili saltpeter used by the world. Germany possesses but little water-power so that this process is of only indirect interest in connection with German chemical industry.

2. Nitrogen may also be fixed by calcium carbide at high temperatures. This discovery was made by the German chemists Frank and Caro. $25,000,000 capital is already embarked in this industry by various companies of Europe and America. About 120,000 tons is produced annually, about one-quarter of which in Germany. The crude calcium cyanamide (about 20 per cent N) may be used directly as a nitrogenous manure or may be made to yield ammonia. The production of calcium carbide involves the use of electric furnace and hence cannot be carried on economically on a very large scale in Germany owing to the limited water-power available.

3. Nitrogen and hydrogen may be combined at higher temperature and especially under high pressure. The long known fact that the reaction, $N_2 + 3H_2 = 2NH_3$ is realized to a very small extent at high temperatures has been investigated in recent years by Haber and Le Rossignol at Karlsruhe, and, guided by the principles of modern physical chemistry, Haber has elaborated, after overcoming extraordinary technical difficulties, an industrial process which promises to be of great importance in the future. The most advantageous conditions were found to be: Pressure, 200 atmospheres; temperature, 500 deg. C.; catalytic agent, osmium, uranium, etc.

Production of ammonia by the Haber process has been carried out on a commercial scale by the Badische Anilin Company since the summer of 1913, and a plant capable of yielding 130,000 tons of sulphate of ammonia per annum was to have been ready during the present year. Inasmuch as the German Color Syndicates have severed their connection with the Norwegian nitre undertaking, it would appear that they regard the Haber ammonia process as being more likely to be capable of capturing the inorganic nitrogen market of the world.

This synthetic production of ammonia obviously involves cheap hydrogen. I have already referred to electrolytic hydrogen, but there are cheaper sources. Thus water-gas contains theoretically equal volumes of hydrogen and carbon monoxide; the carbon monoxide (boiling point—192 deg. C.) can be removed by liquefaction from the hydrogen (boiling point—253 deg. C.). Similarly the nitrogen required for the process is obtainable from the fractional distillation of liquid air. The synthesis of ammonia thus dovetails with the possibilities of cheap low-temperature production for which the world is so largely indebted to the German engineer Carl von Linde of Munich.

The German ambition to make their combined nitrogen at home does not stop at the production of synthetic ammonia, for there are still large requirements in respect of nitrates (Germany produces upwards of $7,500,000 of nitric acid annually from Chili saltpeter) which have to be satisfied from foreign sources. They hope, however, to fill this gap in the home-production of combined nitrogen by utilizing a reaction discovered by Kuhlmann[14] as long ago as 1839, in which ammonia and air burn to nitric acid in the presence of platinum as a catalytic agent.

POTASH SALTS

Germany appears to be alone in possessing vast deposits of potash salts, whilst the enormous value of these to agriculture was first demonstrated by Liebig and made public by him in his "Application of Chemistry to Agriculture and Physiology" in 1840. This work may without question be regarded as the foundation stone on which agricultural chemistry has been raised.

The celebrated deposits of potash salts were accidentally discovered in 1857, when boring for rocksalt at Stassfurth, near Magdeburg, in Prussia. Their industrial exploitation on an ever increasing scale was begun in 1861 by Grüneberg and Adolf Frank. In 1861 the production of crude potash salts was 2000 tons; in 1912 it was 11,000,000 tons, worth $44,000,000. Ninety per cent is used as manure (about one-third in Germany itself), and 10 per cent in industries (about two-thirds being worked up in Germany for carbonate, caustic, nitrate, alum, chromate, and chlorate, etc.). America is now experimenting with a view to obtaining potassium chloride from feldspar by the method used in the laboratory for determining alkalis in insoluble silicates, and which consists in heating the silicate with a mixture of lime and calcium chloride. Whether it has any commercial future remains to be seen.

This is a matter of prime importance in the United States, as potash salts are there used on an enormous scale, especially for agriculture. Thus they consumed in 1900 Stassfurth potash salts worth $4,200,000; in 1910, $12,200,000, and in 1911, $15,200,000.[15]

EXPLOSIVES

I have already mentioned the importance of nitrates and of nitric acid, and have referred to the employment of the great part in agriculture; of the remainder the major part goes into the manufacture of explosives and into the coal tar color industry.

Black powder or gunpowder is said to have been discovered by the English monk Roger Bacon (1214-1294). Gun-cotton was discovered by Schönbein in Basle and Christian Böttger in Frankfurt in 1846.

Nitroglycerin was discovered by Sobrero in Pelouze's laboratory in Paris in 1847, and first manufactured on a large scale as an explosive by the Swede Alfred Nobel in 1862.

The disruptive properties of gun-cotton are greatly moderated by gelatinising by means of solvents (acetone, acetic ester, alcohol and ether, etc.), and by mixing with nitroglycerin ballistic materials like cordite. and other smokeless powders are obtained. There is another class of explosives which combine great safety in handling with enormous disruptive effect. Picric acid (discovered by Woulfe of London in 1771), but first used by the French under the name of Melinite for filling shells in 1881, and later by the English under the name of Lyddite. More recently this has been replaced by trinitrotoluene, first proposed by Haeussermann in 1891 for filling shells and used by the British Service under the mark "T. N. T." It is even less sensitive to shock than picric acid. "Ammonal," used by the Austrians for shell-filling, is a mixture of T. N. T. with ammonium nitrate, charcoal and aluminium powder. It is both very safe and very powerful. T. N. T. is much used for demolishing bridges. It is so sensitive to shock that it is not exploded on being struck by a rifle-bullet, and when in a shell it withstands the impact of the latter piercing an armor plate.[16]

Tetra-nitro-aniline, obtained by Flürscheim, enjoys the unique position among explosives of having been discovered in this country. It is said to be equally safe and even more powerful than trinitrotoluene.

According to the late Oscar Guttman, the production of nitroglycerin explosives in 1909 was as follows:

[14] Ann. Chem. und Pharm., 1839, 29, 280.

[15] Macnab. "Explosives," Inst. of Chem. Lecture, 1914.

[16] Molinari.

United States, 20,000; Germany, 10,300; England, 8100; Transvaal, 8000; Canada, 5000; Spain and Portugal, 3500; Austria-Hungary, 2300; France, 1500 tons; Switzerland, Austria, Norway and Sweden, 600 tons each; Russia, Italy, Holland, Belgium, 500 tons each; Greece, 175 tons.

Explosives are of enormous importance also in civil life—in mining and engineering modern explosives have greatly accelerated progress and have rendered possible such works as the Panama Canal. They are also being now employed with great advantage in afforestation for loosening the ground in which trees are to be planted. The manufacture of explosives in Germany is very highly developed. The total German production of 40,000,000 kilograms includes dynamite explosives, 10,000,000; ammonium nitrate explosives, 16,000,000 and black powder, etc., 14,000,000 kilograms. There were exported in 1908 explosives of a value of about $5,000,000, and in 1912, $15,000,000.

The world production of explosives is now about 400,000,000 kilograms, or 10 times the German total output. Great Britain has at Ardeer in Scotland, the largest explosives factory (Nobel's) in the world, covering 850 acres, employing 1800 men and 700 women, and producing annually about 16,000 tons of all kinds of high explosives.

ARTIFICIAL SILK

An eminently peaceful industry which is closely related to that of explosives is the production of artificial silk and celluloid. The manufacture of artificial silk has grown up during the past twenty-five years, for this product was first shown by Count Hilaire de Chardonnet at the Paris Exhibition of 1889; he discovered the method of its preparation while a student in the Ecole Polytechnique at Paris, and in 1891 formed a company at Besançon with a capital of $1,200,000 for its manufacture.

The chief kinds of artificial silk are: (1) Nitrated cellulose (soluable in alcohol-ether) silk (denitrated by ammonium sulphide) (Chardonnet silk). (2) Ammoniocupric oxide cellulose silk (Pauly, Fremery, or Urban silk, of the Vereinigte Glanzstoffabrik, Elberfeld, 1897). (3) Viscose-silk (CS_2 in presence of NaOH or Ca (OH_2) on cellulose) (Cross and Bevan). (4) Acetate-silk (acetic acid on cellulose) (Cross and Bevan).

Germany produces about 2,000,000 kilograms, value about $6,000,000, exports 600,000 kilograms, and imports 1,800,000 kilograms; the imported is principally "alcohol silk," due to disadvantageous alcohol tax in Germany. Germany is the principal user of artificial silk, although the fundamental discoveries upon which the manufacture is based are largely due to French and English chemists. The world production is estimated at about 7,000,000 kilograms.

The distribution of the industry may be gathered from the following: France, 7 factories; Germany, 8; Belgium, 3; England, 2; Spain, 1; Austria-Hungary, 4; Russia, 3; America, 3; Japan, 1.

Great profits have been made out of artificial silk (some of the companies paid 50 to 100 per cent dividends), and the price has greatly fallen since its introduction from $7 per kilogram in 1903 to $4 in 1906, and $3 (poorer qualities $1.50 to $2) in 1910.

The celluose industries furnish a particularly striking example of the manner in which chemical research and invention are able to enhance the value of the kindly gifts of the earth. Thus, 1 cubic meter of wood has value as fuel about $1.50; (after boiling with lime, soda and sulphite) as paper pulp, $8; ditto as paper, $14; and as pulp converted into artificial silk, $400 to $1200.

INDUSTRIES DEPENDENT ON SYNTHETIC ORGANIC CHEMISTRY

It is out of the profound study of synthetic organic chemistry which has been made during the past sixty years that the industries of artificial dyes, drugs, and perfumes have incidentally arisen. The earlier and pioneering achievements in synthetic organic chemistry are well distributed among the nations of Europe,[17] but during the major part of the sixty years the great bulk of the discoveries in this domain have been made in Germany. Organic chemistry is, perhaps, the branch of science which more perfectly suits the German mind and temperament. It involves the possession of those qualities in which Germans are so pre-eminent—the capacity for taking an infinitude of pains, the capacity to anticipate difficulties, and organize means to circumvent them. It is, moreover, only possible to make substantial advances in the problems of organic synthesis if the master has at his disposition a number of highly qualified and docile assistants and apprentices; in a word, the master must be at the head of a large and efficient school of research. It is in the possession of such schools of research, both in the universities and in the chemical factories, that Germany has by two generations the lead of all other countries in the world. While most of the professors of chemistry in British universities and colleges have under great difficulties and without any sort of encouragement been more or less successful in building up such schools of research, which are, however, by no means slavish imitations of the German model, the chemical manufacturers of England, have, with some notable exceptions, failed to establish anything worthy of the name of research laboratories in connection with their works.

It is in respect of the works research laboratory that there is the greatest contrast between the chemical industries of Germany, and those of other countries, and it is not surprising, therefore, that the present war should have served to emphasize the class of chemical products for which Great Britain is almost entirely dependent on Germany.[18] It is precisely those products —artificial dyestuffs, artificial drugs and artificial perfumes which are the outcome of the works research laboratories, that are now in many cases unobtainable in consequence of the cutting off of the German sources.

The seriousness of the situation is apparent from the following figures, relating to dyestuffs alone: The value of dyestuffs consumed in England annually is $10,000,000, and the value of trade in which these dyestuffs are employed is $1,000,000,000, whilst upwards of 1,500,000 workmen are dependent upon these industries. The total value of dyestuffs imported into the United Kingdom in 1913 was $9,460,275, of which Germany contributed $8,654,105.

Perhaps the most concise way of conveying a superficial idea of these industrial products of organic synthesis will be by means of the following classification.

I. *Artificial Products.*—Colors first obtained from aniline by Runge in 1834, by the action of bleaching powder. Aniline colors: Mauve was discovered by Perkin in 1856 and Magenta by Verguin in 1859. Azo-colors[19] were discovered by Griess in 1859, and introduced on an extended scale in 1878. The azo-colors have achieved an enormous importance and have practically banished cochineal and logwood from the dye-works. Some 2000 azo-colors in use. Congo-colors, substantive cotton dyes, were discovered by C. Böttiger in 1884.

[17] England and France were, however, more especially to the fore.

[18] Only about one-tenth of the annual value of dyestuffs consumed in England is produced in England.

[19] Both azo and eosin colors were kept as secret products, but the colors were investigated by Hofmann and their mode of production published, to the great consternation of the inventors.

It must not be supposed that British color manufacturers have been idle from the days of Perkin; thus in 1880 a very original departure was made by Messrs. Read, Holliday and Sons, who introduced the principle of developing azo-dyestuffs on the fiber with their so-called ingrain or ice colors. Some of these have achieved a great success, thus 2000 tons of p-nitraniline are now annually manufactured for the production of nitraniline-red and similar colors.[20] Again, the discovery of primulin and the colors which can be derived from it, by A. G. Green in 1887, is another very notable achievement.

Eosin colors were discovered by Caro in 1873.

II. *Artificially Produced Natural Products.*—This group contains substances occurring in nature and long valued by man. The chemical nature of these substances has been carefully ascertained by chemists who have then deliberately set to work to devise means for their artificial preparation at such a cost as to compete with and ultimately supplant the natural product. These campaigns against the commerce in the products of nature undoubtedly constitute one of the most remarkable phenomena in the history of the world. Bear in mind, it is the production and supply to man of the actual products of nature, but more cheaply than they can be produced and supplied by Nature herself. These endeavors have already been successful on a very large scale.

Alizarin (the essential principle of the madder root) was first synthesized by Graebe and Liebermann in 1869. At the time of this discovery, the world production of madder was 50,000,000 kilograms roots (1½ per cent alizarin), representing 500,000 to 750,000 kilograms alizarin, value $11,250,000. In 1870 France had 20,000 hectares (50,000 acres) under madder cultivation, which soon disappeared after the introduction of the artificial product.

The production of artificial alizarin was: 1873, 100,000; 1877, 750,000; 1884, 1,350,000; 1900, 2,000,000 kilograms (four-fifths of this was produced in Germany).

A great number of most valuable artificial dyestuffs, more or less closely related to alizarin, but not occuring in nature, have been prepared by chemists, and the total value of the alizarin-color exports of Germany at the present time is about $5,000,000.

Indigo.—This most highly prized blue dyestuff of both the ancient and the modern world was first artificially synthesized by Adolf Baeyer in 1880, but it required seventeen further years of unremitting and laborious investigation in the works of the Badische Anilin und Sodafabrik at Ludwigshafen, and the investment of nearly $5,000,000 before laboratory synthesis was translated into a commercially successful industry, for it was in 1897 that the artificial indigo was put on the market.[21]

In 1896 the world production of plantation indigo (100 per cent) was 6,000,000 kilograms, value $20,000,000; four-fifths of this was British, obtained from 1,500,000 acres in British India. In 1904 only 500,000 acres was under cultivation, and in 1913, only 300,000 acres (see Table IV.).

Table IV—Indigo

	British East Indies		Germany	
	Cwt. Exports,	Value	Imports	Exports
1896	188,337	$17,848,350	$5,180,000	$1,597,750
1899	135,187	9,901,595	2,077,250	1,961,250
1902	89,756	6,174,185	921,750	4,615,500
1905	49,252	2,782,025	300,500	6,430,250
1908	32,490	2,124,245	220,500	9,663,750
1911	16,939	1,125,000	111,500	10,457,500
1913-14		$300,000 to $350,000		

[20] G. T. Morgan, "Modern Dyes and Dyeing," Roy. Dublin Society, 1914. Cain and J. F. Thorpe, "The Synthetic Dyestuffs and Intermediate Products," 1913.

[21] Baeyer's first patent for the synthesis of indigo from o-nitrocinnamin acid was taken out in 1880, and by 1907 there had been no less than 316 patents obtained in Germany for processes connected with the preparation of indigo.

The price of indigo (100 per cent) in 1897 was $4 per kilogram and in 1913 $1.75 per kilogram.

By varying the ingredients in the indigo-synthesis, many very valuable dyes related to indigo have been obtained. Thus the chlorine and bromine substituted indigos are manufactured as ciba-blue, brilliant-indigo and bromo-indigo. Again with sulphur instead of oxygen, thio-indigo-red, and thio-indigo-scarlet are obtained. Moreover, by using the anthracene-grouping in the indigo-synthesis a number of most important colors have been obtained, *e. g.*, indanthrenes, of extraordinary fastness to light; alizarin-indigo; algol-colors (Rob. E. Schmidt), in all varieties of color, and of the greatest fastness to light. The discovery of these valuable dyestuffs provoked zealous emulation on the part of the azo-color chemists, who responded by placing some very excellent new products on the market under the name of benzolight colors.

Antique or Tyrian purple was perhaps the most highly prized of all colors in the ancient world. We know from Pliny that this dye was obtained from a rather rare snail living in the Mediterranean, and which he describes under the name of "purpurea." Paul Freidländer, of Darmstadt, succeeded in 1909 in extracting this color from certain glands of two different species of snail—*murex brandaris* and *murex trunculus*—which appeared to correspond to Pliny's description of "purpurea." He removed these glands from 12,000 individual snails, developed the color by a short exposure to sunlight, extracted it with suitable solvents and recrystallized it from quinoline. In this manner he obtained only 1½ gram of the coloring matter, so that its extreme costliness, which Freidländer estimates at about $10,000 a kilogram, is not surprising.

On investigating the chemical nature of this color he found that it was identical with the already known synthetical compound 6.6′-dibromindigo.

Drugs and Perfumes.—Not less remarkable are the achievements of organic synthesis in connection with pharmaceutical and perfumery products.

The production of artificial drugs and perfumes is in general only a branch of the artificial color industry, for in many cases the raw materials are the same, while the methods of investigation and synthesis are, of course, identical. But whereas the artificial color industry started in England, that of artificial drugs is entirely of German origin, and may be said to begin with the discovery by Liebig of chloroform in 1831, and of chloral hydrate in 1832. It was in 1869 that the chemical works of Schering, on the suggestion of A. Liebreich, produced chloral hydrate as a commercial article.

In 1887 began the discovery of artificial antipyretic drugs, the rivals of the natural quinine. The first of these was antifebrin, the properties of which were discovered accidently in consequence of a mistake. A specimen of acetanilide in a Strassburg pharmacy was erroneously supposed to be naphthalene, and was served out as such for some pharmacological experiments by Kahn and Hepp. On being taken, internally, its antifebrile effect was observed. Fortunately there was enough left for analysis, and it was found that the supposed naphthalene was the long known acetanilide, which soon acquired a great vogue for this purpose. About the same time antipyrin was discovered by Knorr, who erroneously thought that it was chemically related to quinine, and that it would, therefore, not improbably possess antifebrile properties. Direct experiment showed that it did actually possess these properties in a high degree, but subsequent research showed that it was in no way chemically related to

quinine. These and numerous other artificial antipyretics have been a great source of income to their inventors in consequence of the continued prevalence of influenza during the past quarter of a century.

During the period that antipyrin was protected by patent it was sold at $30 per kilogram, while on the expiration of the patent the price was reduced to $5 per kilogram, which still allows a good margin of profit.

These discoveries have led to the systematic study by direct experiment on animals and human beings of innumerable chemical compounds with a view of ascertaining their physiological properties. The enormous amount of most laborious work which has been carried out in connection with synthetic drugs may be gathered from the fact that up to 1912 about 5000 artificial products had been found to possess therapeutical value of one kind or another, but, of course, comparatively few of these have permanently established themselves in medical practice. Time does not permit me to do more than refer briefly to some of the simpler and better known synthetic drugs.

Thus of antipyretics, which have or have had some considerable vogue, are: Antipyrin; tolypyrin (dimethyltolylpyrazolone); salipyrin (antipyrin-salicylate); antipyrin mandelate (tussol, for whooping cough); neopyrin; pyramidon (three times as strong as antipyrin) (dimethylamino-antipyrin); antifebrin; phenacetin (cheapest antipyretic excepting antifebrin, about $1.50 per kilogram, and less poisonous than antifebrin); lactophenin, lactyl-p-phenetidine; aminophenacetin or phenocoll (also has an antiseptic action).

The above series derived from aniline affords a good illustration of the dependence of physiological properties on chemical constitution. Aniline itself is a powerful antipyretic, but is extremely poisonous, owing to its ready absorption and action on haemoglobin. By introducing the acetyl group the toxic properties are much reduced owing to its greater stability, although acetanilide is slowly hydrolyzed with liberation of analine, so that after a time the symptoms of aniline poisoning may supervene. The observation that acetanilide is partially oxidized in the system to *p*-aminophenol led to derivatives of the latter being tried. Thus phenacetin has been found to possess powerful antipyretics and greatly reduced toxic effects[22]

Hypnotics.—Sulphonal was accidentally discovered to possess hypnotic properties in connection with experiments on the transformations of sulphur compounds in the animal system. A dog, which had been dosed with the newly discovered sulphonal, in Baumann's laboratory at Freiburg, i.B., was found to fall into a deep sleep.

More powerful hypnotics were found to result from introducing further ethyl groups:

$(CH_3)_2C(SO_2.C_2H_5)_2$. Sulphonal

$(CH_3)(C_2H_5)C(SO_2.C_2H_5)_2$ Trional

$(C_2H_5)_2C(SO_2.C_2H_5)_2$ Tetronal.

In connection with the manufacture of sulphonal, I may refer to an interesting difficulty which was experienced by the Elberfeld Color Works owing to the appalling smell of the mercaptan from which it is prepared, and of which Emil Fischer and Penzoldt have shown that the human nose is still capable of appreciating 1/400,000,000 mgrm. In spite of this, German thoroughness has been successful in so perfecting the apparatus in which the manufacture is carried on that no nuisance is occasioned.

Veronal (diethylbarbituric acid) (E. Fischer and Mering, patented by Merck in 1903) is one of the most widely used hypnotics. Although it was formerly supposed to be practically free from toxic properties, in recent years cases of veronal poisoning have been known to occur.

Antineuralgics.—Salicylic acid, one of the first drugs to be artificially prepared (Kolbe, 1860), acetyl-salicylic acid (aspirin), and salol (phenylsalicylate), though extremely simple synthetic products, are almost exclusively made in Germany, with the result that their price has now greatly increased. Even synthetic phenol which is necessary for the above preparations, was exclusively made in Germany and kept down the price of coal-tar phenol. The price of phenol has now enormously increased from 7 cents per lb. to 33 cents per lb., and is likely to go higher. (Pharm. Journal, 1915.)

Anti-gout drugs (Uric acid solvents).—Piperazine (discovered by Hofmann in 1890), lysidine, urotropine (hexamethylene tetramine), atophane (*a*-phenylcinchonic acid).

Suprarenine.—This is of special interest. The active principle of the suprarenal glands known as adrenaline[23] had for some years been found to be of great value for increasing the blood-pressure, contracting the blood-vessels, and arresting haemorrhage. It requires the suprarenal glands of 40,000 oxen to prepare 1 kilogram of adrenaline, but this substance has been artificially synthesized by F. Stolz, and is put on the market as suprarenine by the Höchst Color Works. The synthesis of adrenaline may be presented thus:

Catechol $\xrightarrow{CH_2ClCOCl}$ Chloraceto-catechol $\xrightarrow{CH_3NH_2}$ Methyl-amino-aceto-catechol $\longrightarrow$ Adrenaline Al-amalgam

Natural adrenaline is laevo-rotatory; the synthetic can be resolved by tartrate; the laevo is 15 times as potent as the dextro.

The German color manufacturers are organized into two principal groups or trusts (Interessengemeinschaften). (1) Badische Company, of Ludwigshafen; Bayer Company, of Elberfeld; Berlin Aniline Company. (2) Cassella Company, of Frankfurt; Meister, Lucius, und Brüning, of Höchst.[24]

The share-capital of the above two groups in 1911 was $40,000,000 paying a dividend of 25.8 per cent, and probably now about $60,000,000 dividend, 28 per cent.

In 1860-70 Germany imported about $12,500,000 worth of dyes per year, while in 1912, Germany exported about $50,000,000 and produced about $62,500,000 of dyes.

The composition of the personnel who carry on these German color works is at the bottom of their success. Take the Works of Messrs. Meister, Lucius, und Brüning as an example. In 1913 the composition was as follows: Workmen, 7680; managers, 374; expert chemists, 307; technologists, 74; commercial staff, 611. Contrast with the above the fact that the six English factories now producing dyestuffs employ altogether only thirty-five chemists, while evidence of their relative activities is again furnished by the circumstance that between 1886 and 1900 the English firms took out only eighty-six patents, whereas the six principal German firms were responsible for 948 during the same period.

Having shown that these German coal-tar color manufacturers are without rivals from the commercial point of view, I feel it to be my duty to point out also that their industry is carried on under conditions of labor which are highly creditable to the management.

This vast and highly organized industry of dyestuffs and fine chemicals, which is certainly one of the most outstanding manifestations of the modern German spirit, were formerly very dependent on England for its chief raw material, coal-tar, and it is interesting to

[22]Chemistry of Synthetic Drugs, P, May, 1911.

[23]Discovered by Takamine in 1901.

[24]"German Coal Tar Companies," Textile Mercury, Jan. 9, 1915.

see in Table V how effectually Germany has emancipated herself from a control which might at any time become irksome or even paralyzing.

Table V—German Coal-Tar Production

	Coke Ovens, Tons	Gas Manufacture, Tons
1897	52,000	
1900	93,000	
1904	277,000	225,000
1908	632,400	300,000

In 1908, 40,000 tons was still imported from England, and in 1909, 18,000 tons, but 35,000 was also exported.

In 1900 the German production of coal-tar was only about one-half of that produced in England, while by 1912 it had equalled if not surpassed the English production. Again, in 1880, Germany used 1400 tons of pure anthracite of which only 200 tons was of German origin, while at the present time the 5000 tons now employed in Germany is all produced there.

The phenomenal increase in the German coal-tar production has depended on a similarly rapid development of the German iron and steel industry, which has entailed an enormous demand for metallurgical coke in the production of which the greatest attention has been devoted by Germany to the recovery of the byproducts—tar, gas, ammonia, etc.

In England the quantity of coal-tar treated was 175,000 tons in 1870, and 640,000 tons in 1880; at present over 750,000 tons is treated.

Synthetic Perfumes.—With regard to the synthetic perfume industry, the facts are in many respects essentially similar to those in connection with the artificial dyestuffs. The production of artificial perfumes, in many cases the identical substances which are produced by nature, has assumed very large proportions in Germany, the annual output being estimated at about $12,500,000. It is particularly noteworthy that one of the first steps in the realization of this remarkable achievement of artificially building up the natural perfumes was also made by William Henry Perkin, who in 1868 succeeded in synthesizing coumarin, the highly valued odoriferous principle of the woodruff (*asperula odorata*).

The effect of artificial synthesis on the price of natural perfumes may be gathered from Table VI.

Table VI

	Price of 1 Kilogram—Natural	Synthetic
Coumarin	$125	$6.25
Vanillin	250	7.50
Heliotropin	750	2.50

THE CHEMICAL SITUATION IN GREAT BRITAIN

The facts which I have brought forward speak for themselves and proclaim in the most convincing manner the stupendous progress which has been made by Germany in the chemical industries during the past 40 years. It is equally certain that England, once preeminent for chemical manufactures, has not progressed at the same rate and is at the present moment suffering much inconvenience through being so largely dependent on German chemical products of one kind and another. The country is now reaping the harvest of humiliation which it has sown for itself in spite of the warning repeated *ad nauseam* by the chemical profession during a whole generation. The systematic neglect of chemical science and the failure by manufacturers to utilize the services of highly qualified chemists, could only lead to the result that all the industries which are dependent on a profound knowledge of chemistry should tend to disappear from England's midst and pass into the hands of those who are prepared, not only to apply new chemical discoveries to industry, but even to prosecute the most varied chemical investigations in the hope of sooner or later making discoveries which shall be of advantage to their commercial undertakings.

The mischief caused through the neglect of chemistry by practical men in this country has been so subtle that to a large extent it has remained concealed from the average man of intelligence and from the governmental classes. During the past 40 years our country has been accumulating wealth in an altogether unprecedented fashion, so that the loss or restriction of some industries appeared a matter of unimportance to political observers taking only a broad and superficial survey of the national resources. The whole of our arrangements have evolved during the past half century on the assumption that this country would never again be engaged in a European war, while still more recently the new democracy has vainly boasted that it could prevent such a war by means of a general strike. The year 1914 has seen the dissolution of many fool's paradises and has given the *coup de grace* to all these vain imaginings, with the result that we find our vast textile industry in serious peril because the much smaller dyestuff industry has been complacently allowed to slide into the hands of our sagacious and more painstaking enemies. The same carelessness and want of foresight had even allowed us to become dependent on Germany for some of the most important materials used as explosives, *e.g.*, trinitrotoluene, and for many of the most valued drugs required alike by our army, navy and civil population.

The complete breakdown in our supply of fine chemicals, which is the direct outcome of the disregard of the constant warnings emitted by scores of British chemists, has led the Government of the day to intervene and attempt to remedy the intolerable state of affairs which has arisen in connection with the supply of coal-tar colors.

THE PROPOSED BRITISH COAL-TAR INDUSTRY

We devoutly hope that success will attend the endeavor to establish the coal-tar industry in these Islands on the largest possible scale. Whatever the ultimate scheme adopted may be, I would venture to point out that it must be based on a clear understanding of the following considerations:

1. That the provision of the required chemicals during the continuance of the war is one thing, and that their production on a commercial basis after the cessation of hostilities is quite another matter.

2. It appears to me that in order to provide the needful supply during the war, the only reasonable course is to assist in every possible way those firms which are already making similar or closely allied products so as to enable them to produce their present goods on a larger scale, and as far as practicable to undertake the manufacture of others which are urgently required. The immediate problem will be also greatly facilitated by utilizing supplies obtainable from neutral powers, and more especially from Switzerland, which is the only country, other than Germany, in which the manufacture of dyestuffs and similar chemical products has been vigorously prosecuted. As a matter of fact, Mr. Runciman admitted in the House a short time ago that the Government had granted licenses to trade with the enemy in the matter of dyestuffs.

3. As regards the prospects of the home industry after the war, it will require "nursing." I use the term advisedly in order to obviate the employment of another and much more familiar one which is so dear to some politicians and so hated by others; it will require nursing for a much longer period of time than has hitherto been mentioned. In this connection I would point out that the sum of $50,000 a year for ten years, which it has been proposed to guarantee for research purposes, is absurdly inadequate.

4. If the industry is to prosper it will not only have to manufacture materials already known. but also con-

tinually to be introducing new products of its own discovery, as well as constantly to be seeking to produce more economically a great number of auxiliary chemicals required in the manufacturing processes. It is also essential that the undertaking should branch out into the manufacture of other materials as occasion may arise for advantageously utilizing byproducts.

5. The competition which the industry will have to suffer from Germany is likely to be much more serious than is generally supposed, because it must be remembered that England only takes, as we have seen, about one-fifth of the total German exports of dyestuffs, so that it would be comparatively easy for German firms specially to reduce the price of the goods sent to England. They have already done this in America when attempts have been made to start an aniline industry there. It is particularly significant, and augurs ill for the prospects of this scheme, to rehabilitate the coal-tar color industry, that the latter has failed to flourish anywhere, excepting on German soil, and that countries with fiscal systems entirely different from our own have been no more successful in this respect than have we ourselves.

6. It will certainly be necessary that expert chemical knowledge should in the future be much more highly remunerated than it has been in the past, otherwise the supply of able and properly qualified men will not be forthcoming. The flow of men of high-grade intelligence into a profession is determined by the prizes which the profession has to offer, in the form of money and social position. Consider the great stream of able men who are attracted to the English Bar, in which profession the prizes, although limited in number, are of the most substantial kind, with the result that the successful leaders are selected by the fiercest competition in a very wide field.

If there is to be a large influx of high intelligence into the chemical profession, it will be necessary that there should be some very different prizes from the paltry bait which is offered at the present time, for the study of chemistry in this country now only draws those men who either have or think they have an overpowering zeal and passion for the science, to which they devote themselves against the advice of their friends, and in spite of the warnings of the professors of chemistry, by whom they are initiated.

Notwithstanding the absence of material inducements, I venture to say without fear of contradiction that there is more original investigation being prosecuted in this country by chemists than by any other body of British men of science, and this I attribute to the fact that such a large proportion of our number have either been at German universities or are the pupils of those who have been at these centers of research. Nor are any of us, I am sure, even during this unfortunate crisis, unmindful of the hospitality and the inspiration which we have received in the schools of the enemy.

7. If the proposed undertaking is to succeed, real chemists must be on the directorate, and in a sufficient proportion to give effect to their views. Many men of science are excellent business men. What does experience teach in the case of flourishing chemical industries which we fortunately still have among us? What does not the firm of Messrs. Brunner, Mond & Co., for example, owe to the late Dr. Ludwig Mond, F.R.S.?

8. In attempting to establish a commercially successful coal-tar company on a large scale in this country, I venture to think that the Government have undertaken a task which they will find to be surrounded with difficulties of quite a different order from those which they have had to encounter in some of their most striking previous legislative acts, such as the provision of salaries for members of Parliament, the granting of Old Age Pensions, and the establishment of a compulsory system of Insurance. These are matters in which if the Government dictate we are obliged to obey, but the commercial success of an industry which is based upon progressive scientific investigation depends upon factors so subtle and elusive that they cannot be coerced even by a majority of the House of Commons.

9. If the chemical industries are to be rehabilitated in England, there must be a complete change in the attitude of mind towards science in general, and towards chemical science in particular, among the influential classes of the population, and it will certainly not be effected by following the precept "business as usual." but by pursuing a policy which is the exact opposite of what is implied by that vulgar and undignified phrase.

Synopsis of Recent Chemical and Metallurgical Literature

Potash in the United States

In discussing the possible sources of potash in the United States before the New York section of the Mining & Metallurgical Society of America, Mr. A. H. ROGERS mentioned the work of the Government on the brines and deposits in desert basins, also the investigations on alunite in Utah, and the possible utilization of the giant kelps of the Pacific coast. Mention was made also of the potash-bearing silicates, feldspar and leucite. The former contains about 16 per cent and the latter 21 per cent potash. In speaking of the work of Cushman and Coggeshall on extracting potash from feldspar, Mr. Rogers said: "This includes fine grinding of feldspathic material and mixing with 20 per cent of burned lime. This mixture is deposited in a thin layer on a belt which travels under an arrangement which allows drops of a concentrated solution of calcium chloride to fall on it. The result is the formation of little balls having considerable hardness which, being screened out, are furnaced in an ordinary cement kiln; such of the powdered rock as has not been agglomerated is returned to the head of the belt. The heated agglomerates contain the potash of the feldspar as chloride, which is then leached out and recovered by evaporation. Messrs. Cushman and Coggeshall have experimented on a large scale with this process, and as the results of their work have estimated that potassium chloride can be produced for $31.32 per ton, or about 62 cents per unit K_2O."

Speaking of experimental work on leucite, Mr. Rogers continued: "We have tried both wet and dry treatment; the former has been possible because, in contrast with feldspar, leucite is very easily decomposed. Another curious feature about leucite is that, in distinction from most silicates, when decomposed by wet acids it yields its silica in granular form and not gelatinous. We found that by treating with sulphuric acid, to which a little hydrochloric acid was added, complete solution of the bases resulted, and we thought that this might solve our problem. However, it speedily developed that the mixture of sulphates was about as hard to separate into its constituents as the rock. Digestion of leucite with caustic lime under a high pressure was also tried, and this procedure was varied by using caustic soda, and even sodium chloride, the idea being that soda might replace the potash better than lime. From all of these tests some results were obtained, but not enough to be encouraging. Treatment of the rock with sulphurous acid gas at temperature ranging up to 1200 deg. C. was tried, and also the Hargreaves process, which is employed for making sodium sulphate out of salt by passing steam and SO_2 over the salt at a temperature of about 500 deg. C. These yielded a little soluble potash,

but results were not encouraging. We have, therefore, for some time abandoned this wet work.

"Of dry processes, I think we have tried almost all those which seemed to offer any possible chance of success. We speedily found that if you heat a mixture of leucite, lime and gypsum to the proper temperature, the potash could be quantitatively extracted as sulphate. Bearing in mind some of the experiences of cement manufacturers, that the small amounts of alkalis contained in their limes are volatilized, a good many experiments were made with this in view, but we were not altogether successful as sometimes a large percentage would be driven off, at other times but little. As previously stated, we tried heating the leucite with rock phosphate, without result. We also tried the Cowles process which, as perhaps you remember, was devised to extract alumina from clay. By the scheme proposed, a mixture of salt and clay was compressed into briquettes, and heated, whereby hydrochloric acid was given off and an alkali-silico-aluminate was formed. This compound was then to be decomposed by heating with limestone to form a lime silicate, leaving a soluble alkali-aluminate. Some briquettes were made up, and heated in Mr. Cowles' furnace, but very unsatisfactory results were obtained.

"We eventually concluded that unless alumina could be recovered also, the treatment of silicates was hopeless from a commercial point of view. This, I think, has been the conclusion of all investigators, as nearly all recent patents aim to produce something beside potash. As a great many others have learned, we found that when silicates are heated with limestone the potash is set free, but we also found that if the CaO is in the proper proportion, all the bases seem to be set free; at any rate, all except the magnesia. The alkali combined with alumina, and possibly also the ferric oxide and the alkali-aluminate, being soluble compounds, could be leached out. This is a point which has never been recorded by any other investigator, and the ability to recover alumina in such a simple way is, we believe, a solution of the problem. The process consists of grinding a mixture of leucite and limestone in proper proportions, just as in cement manufacture, and furnacing it in a cement kiln. The clinker produced is somewhat similar to cement clinker, and is simply ground and leached. Nothing but alkali and alumina go into solution, and those can be separated just as in bauxite refining. The resulting aluminas is just as good as that produced from bauxite. We have been doing this for about a year now in a small experimental kiln; and while, due to difficulty of temperature control, we do not always get high extraction, we consider it possible that, with the uniform conditions possible of maintenance in a large furnace, we can recover 75 to 80 per cent of these two substances."

Gold and Silver

Cyaniding at the Chiksan Mines, Korea.—In a paper presented to the American Institute of Mining Engineers for the meeting at San Francisco, September, 1915, Mr. Charles W. De Witt, of Seikwan, Korea, describes the metallurgical practice of the Chiksan Mining Company. A flow-sheet is shown in Fig. 1. The ore is quartz of medium hardness, and the average assay value in gold is $6.95 per ton. The mill originally contained two Nissen stamps; two more were added later. Subsequently two batteries of California stamps were installed, and gradually the Nissen stamps were replaced by ordinary gravity stamps. The only reason assigned for the removal of the Nissen stamps is the "wear and tear." Battery screens are thirty-mesh, and both inside and outside amalgamation are used. Pierce riffles follow the plates. After amalgamation the unclassified pulp is concentrated, the concentrates being shipped to the United States. Table middlings are reconcentrated on other tables without intermediate regrinding. Tailings are classified into sand and slime by an Akins classifier, and the sand is leached. Slime is settled in ponds, and may be cyanided later if found sufficiently valuable. The sand vats are filled and emptied by coolies carrying "jiggies." A treatment cycle, including loading and unloading, occupies four days. Precipitation is on zinc in boxes, and the precipitate is treated with acid, dried and melted in the usual manner.

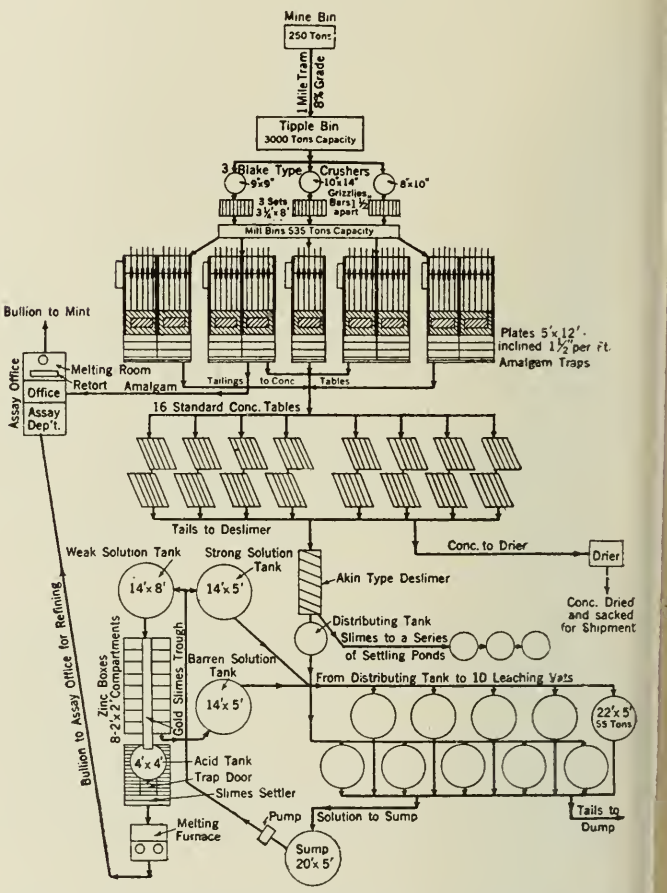


FIG. 1—FLOW SHEET OF THE REDUCTION PLANT OF THE CHIKSAN CO.

The performance of the stamp mill for the year ended Dec. 31, 1915, was:

Tons crushed	46,402
Average assay value	$6.956
Gross value (head assays)	$322,770
Bullion (21,872 oz.):	
Gold	$231,932
Silver	5,794
Concentrates (414.33 tons)	31,388
Total	$269,114
Milling cost, per ton crushed	$0.67
Average assay value of concentrates	$75.75
Stamp duty per 24 hr	4.12 tons

The costs and recovery at the cyanide plant for the year Jan. 1, 1914, to Jan. 1, 1915, were:

	Per Ton	Total
Recovery	$0.799	$29,426
Cyaniding costs	0.335	12,462
Profit	$0.464	$16,964

Total recovery from reduction plant was:

Bullion (28,105.6 oz.):	
Gold	$259,013
Silver	8,062
Concentrate	31,388
Total output	$298,463

Effect of Carbon in Contact with Auriferous Cyanide Solutions.—The subject of precipitation of gold in cyanide solutions by forms of carbon is again discussed in *Bulletin* No. 127, I. M. M., by Mr. W. R. FELDTMANN. He has had occasion to investigate the precipitating action of some "graphitic" ores, and has gathered other data on charcoal precipitation. The graphitic or carbonaceous schists of West Africa precipitate gold from cyanide solutions, and the low extractions obtained there are partly due to reprecipitation of gold by the schists. An analysis of the graphitic schist shows 10.80 per cent "graphite, etc." (by difference). The close analogy between the actions of West African graphitic schists and charcoal is shown in the following points:

1. Gold is precipitated (in the case of the schist in a measure roughly proportional to the amount of carbon present).

2. The gold thus precipitated is not soluble to any appreciable extent in fresh cyanide solution.

3. It is to a large extent soluble in alkaline sulphides.

4. After dissolving the gold in alkaline sulphides the precipitating capacity of both schist and charcoal is renewed practically in its entirety.

The author summarizes his conclusions as follows:

1. It has been demonstrated that the graphitic schists of West Africa precipitate gold from auriferous cyanide solution in a manner which is, in all important respects, analogous to the action of charcoal under like conditions.

2. The gold is precipitated on the charcoal (and on the schist) not as metal but as a compound—possibly a carbonyl aurocyanide.

3. The gold compound is decomposed and the gold dissolved to a considerable extent by alkaline sulphide solutions (judging by the results of a large number of tests, the re-solution is effected rather more easily from the schist than from charcoal).

Whether the discovery that alkaline sulphide solutions will dissolve gold which has been precipitated on the carbonaceous schist can be turned to practical utility in the cyanide treatment of ores containing such schist, is the subject of experiments at present being carried on. By post-treating, with sulphide solutions, sand residues from which a maximum possible extraction had previously been recovered by cyanide treatment, a further extraction has been obtained from a large number of samples, and there is some promise that an economical post-treatment may be evolved on these lines. The precipitation of the gold from the sulphide solutions (in which the gold is held as alkaline aurocyanide with hardly any free alkaline cyanide, but a large excess of alkaline sulphide) appears to be best effected by contact with metallic copper.

Effect of Mineralized Waters in Cyanide Mills.—At some of the cyanide plants in western Australia where good water cannot be obtained it is necessary to use water heavily charged with mineral sulphates, chlorides and carbonates. What is locally known as "fresh" water is obtained from shallow wells, while "salt" water comes from underground drainage. Both classes of water have to be used at the Sons of Gwalia. A description of their use and treatment is given by Messrs. THOMAS B. STEVENS and W. S. BRADLEY, in *Bulletin* No. 127, Inst. of Min. & Met. Analysis of the "fresh" water shows 1.6643 grams solids per liter, while the "salt" water contains 55.744 grams solids per liter. The principal salts are sodium chloride, magnesium chloride and sulphate and calcium carbonate and sulphate. From their experience the authors make the following recommendations for the use of mineralized waters:

1. If "salt water" is used it is not usually possible to obtain a protective alkalinity, but it is advantageous to add a small amount of lime in order to make use of the protective action of precipitated magnesium hydrate.

2. A mixture of "salt and fresh waters" is to be avoided, as dilution of the sodium chloride present causes precipitation of insoluble calcium and magnesium salts, but if they have to be used the addition of lime to produce a protective alkalinity is to be desired.

3. The use of all "fresh water" is by far the most satisfactory, but sufficient lime should be added to it to render it alkaline before it is introduced into the treatment plant.

4. Unless there be other adverse reasons against it, crushing in cyanide solution is to be favored when using mineralized water, as the quantity of "make-up water" required is kept at a minimum by doing so.

A great deal depends on knowing the exact composition of the water, and work done in finding out exactly how the positive radicals contained in the dissolved salts are combined with the negative radicals is time well spent.

Tube-Milling

Injector for Tube-Mill Feed.—In *Bulletin* No. 127, I. M. M., Mr. N. CARLESS describes a device used at the Waihi Grand Junction mill for feeding pulp to the tube-mills. The injector is shown in Fig. 2.

"In the smaller mills the feed nozzle is 1¼ in. inside diam. The nozzles discharge into a larger pipe which

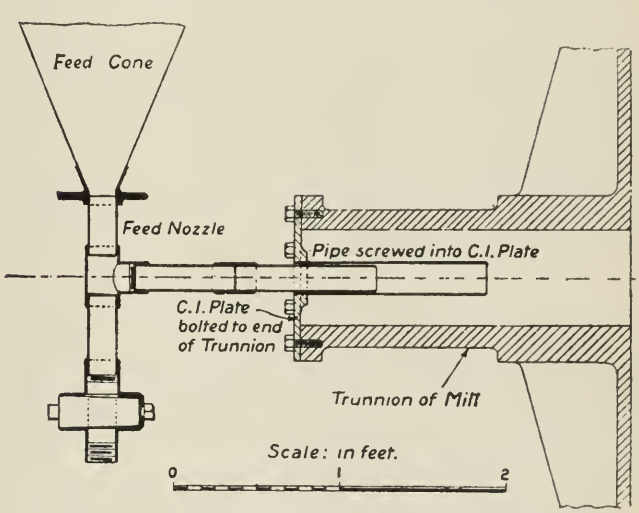


FIG. 2—INJECTOR FOR FEEDING PULP TO TUBE MILL

is bolted on to the end of the tube-mill. A clearance space of ⅛ in. is left around the feed-pipes, hence the pulp discharging into the mill causes a current of air to enter between the two pipes, thus preventing any chance of overflow of pulp at the inlet end.

"It has been found that the best results take place when the pulp passing into the tube-mill contains about 40 per cent of moisture. Experimental work is in hand, with a view of introducing thicker pulp into the mills."

Flotation

Testing Oils for Flotation Process.—An outline of methods for testing oils for the flotation process is published in *Australian Mining Standard* for April 8, 1915, by Mr. J. Coutts. Of the many tests required for this process, one of the most important is the testing of the active floating agent. Conditions of the test should follow as closely as possible the presumed actual conditions of operation. The following remarks pertain mainly to eucalyptus and resinous oils.

Certain standard materials are necessary. (1) Ore sample: A thoroughly representative sample of the material to be treated is dried, crushed to pass 60-

mesh screen, and weighed into 1-lb. lots ready for use. (2) Sulphuric acid: A solution containing 0.405 grams H_2SO_4 per liter, 1 cc. of which equals 2 lb. pure acid per ton, when working with 1 lb. of ore. (3) Oil: A standard oil sample is that oil which has been found to meet the requirements of the work, upon which all future calculations are based and comparisons made. It is stored for use in suitable bottles. (4) Hydrometer: one reading to 0.001.

"In all cases it is necessary to ascertain the sp. gr. of the oil with the view, at least, to future calculations; this may be carried out at any suitable temperature which has been fixed upon as standard; it has been found advisable to check the sp. gr. of the standard oil simultaneously, because of the gradual increase in sp. gr. which takes place owing to the loss of lighter oils by volatilization. A correction for temperature is made by allowing 0.00045 for each deg. Fahr.

"Oil Dropping.—A small burette is used for counting the number of drops in 1 cc. of the oil, also for admitting the oil to the machine during testing operations. The greater the number of drops per 1 cc. delivered by the burette, the greater the accuracy of the test; to obtain a suitable dropper, cut a burette about 8 in. above the cock, almost close to the discharge orifice by dumping up the glass with a blowpipe flame, then grind the outside back to a point so that a minimum surface is presented to the oil drop. The burette should at normal temperatures drop between 80 and 90 drops per 1 cc., when run at the rate of 1 drop per second. The temperature of the oil during dropping test should correspond with the temperature during flotation test.

"Calculations.—Having obtained the number of drops per 1 cc. and the sp. gr., it is easy to calculate the number of pounds of oil per ton of ore, when working on 1 lb. of sample.

Thus $\frac{2240 \times \text{sp. gr.}}{453.6 \times \text{No. drops per cc.}}$ = lb. of oil per ton of ore.

"Miscibility.—It is sometimes desired in practice to use a mixture of oils. When the oil under examination is to be used in conjunction with another, or other oils, they should be wholly miscible in the proportions in which they are to be used.

"The following classification and explanations will serve to convey to the reader a general idea of the methods employed when carrying out various tests:—(1) Flotation of lead, zinc and other sulphides, as a mixed concentrate; (2) differential separation or selective flotation of one sulphide in the presence of other sulphides. The term "differential separation" is usually applied to the selective flotation of lead sulphide from zinc and other sulphides; (3) flotation of copper and iron sulphides.

"General Outline of Scheme of Test.—The testing of oils in the laboratory is carried out by comparing measured quantities (from 3 to 6 drops) of a standard oil, with a similar quantity of the oil under examination; the values being arrived at by comparing the results obtained from each series of tests. Tests are usually made on 1 lb. of standard ore sample in 4 lb. of water at a standard temperature, acidulated with a definite quantity of sulphuric acid; the oil then being admitted; the mixture is agitated in a specially constructed agitating machine, the principle of which being dependent on the object of the test. The float produced is skimmed off, dried, weighed and assayed.

"Test 1.—The flotation of mixed sulphides. Almost any eucalyptol oil which produces a persistent froth, and leaves a gummy residue on evaporation, is suitable for this class of work, the test being carried out as described. An agitating machine may be constructed by cutting a winchester bottle about 10 in. above the neck (a bell jar of suitable dimensions can be obtained), fit four copper baffles 4 in. x 1½ in. wide to a copper band of the same width, push this arrangement hard down into the bottle (the band being first bent to fit the inside circumference of the bottle), the lower ends of the baffles will jam hard at a point where the concave glass begins; the band is then expanded hard against the glass, and held in position by soldering the separated ends. The mouth or discharge end is closed with a rubber stopper, through which is passed a glass or metal tube, fitted with a short rubber tube and clip. The bottle with the baffles in position is inverted and clamped centrally under two pairs of suitable bearings, which carry a ½-in. impeller shaft; at the upper end of the shaft is fitted a driving wheel, and at the lower end a four-bladed impeller, which just has clearance between the lower points of the baffles and the glass; the blades of the impeller have a lateral angle of about 45 deg., and should be driven at about 1200 revolutions per minute, in a lifting direction.

"Test 2.—Differential separation. For differential separation, an oil high in phellandrene is used, which leaves a gummy residue on evaporation. Phellandrene may be tested for by a polariscope. Differential separation is worked in acid and neutral, and in hot and cold liquors, and being still in its infancy, allows of many types of machines and schemes being applied; each different ore requires some modifications, but the principle in main is the addition of medium and aeration from below, which is effected by air jets or suction created by the impeller.

"Test 3.—Flotation of copper and iron sulphides. An oil which gives a deflection by the polariscope of 60 or over is considered sufficiently high in phellandrene for use in copper flotation. Tests are usually made with the apparatus described in Test 1, using cold circuit liquors made slightly acid. In practice the mine water usually contains sufficient acid for the purpose."

Iron and Steel

Automobile Gears.—Robert R. Abbot, metallurgist of the Peerless Motor Car Company, has contributed quite an interesting article on "an example of the development of heat treatment" to the *Sibley Journal of Engineering*. Gears form a very essential part of an automobile. Originally carbon steels were used and they were cyanided; but the hardened surface film was very thin and the gear teeth would fracture. Carbonizing was then employed as the hardened shell can be made as deep as desired. But there is a lack of toughness in a carbonized gear tooth and this led to the use of alloy steels and their heat treatment. Many gears were made of chrome, nickel, and silicon steels containing about 0.5 per cent carbon and were oil-quenched and drawn without carbonizing. The carbon was low enough so that no cementite was present. The alloy gave an extremely strong tooth; the cost of machining was higher than for a low-carbon steel. Such a surface would not wear as well as one containing a higher percentage of carbon. A marked step in advance was then made in the development of the so-called double treatment of carbonized parts; this is applied to either a plain or an alloy steel. When a piece of carbonized steel is hardened at the ordinary hardening temperature, there are three different zones. But if a temperature higher than the hardening temperature is used, the excess substance in the inner and outer zones, namely iron and cementite, becomes less in amount while the martensite becomes greater; briefly the martensite absorbs both the iron and ce-

mentite. As the temperature is raised still further this absorption continued until finally all three zones contain martensite alone. The temperature at which the last of the cementite is absorbed will usually be different from that at which the last iron goes into solution; also the time element for the absorption of the cementite is much greater than for the iron. The temperature of final absorption of the iron increases as the amount of iron originally present in the core decreases. Also the temperature of final absorption of the cementite is higher as the temperature at which the original carbonizing took place is higher. This temperature can also be changed by suitable selection of the material with which the carbonizing is done. In general, all the above factors are adjusted so that the temperature of final absorption of the iron shall be higher than that for the cementite. If the steel is now quenched from above this temperature, there is martensite throughout, but there is a difference in the physical characteristics of the martensite in the three original zones; that in the center zone will be fine grained, while that in the middle and outer will be very coarse. Steel treated in this way will be less brittle than when at the lower hardening temperature, but it will not wear so well because the cementite is no longer present and this is the hardest constituent formed in steel. If the steel is now reheated to the regular hardening temperature, i.e. 1375 deg. to 1400 deg., and then quenched, there is an enormous increase in toughness and also in hardness and wear resisting ability. Microphotographs show that both zones contain the same constituents and in the same relative proportions. However, the structure is entirely different, the cementite in the outer zone no longer exists as brittle sheets, needles or nets, it is uniformly distributed in minute globules which have a maximum durability of wearing surface with a total lack of the former extreme brittleness. The core is very fine-grained and the martensite instead of occurring in a comparatively few large crystals which would tend to promote brittleness now occur as fine crystals embedded uniformly in a matrix of soft iron.

Electrolysis in Concrete Structures

Paints to prevent electrolysis in concrete structures have been investigated by Mr. HENRY A. GARDNER, who presents the results of his tests in the March, 1915, *Journal* of the Franklin Institute. The author concludes that the use of properly made paints on metal embedded in concrete is a safeguard that should not be neglected by the engineer. In the preparation of such paints the vehicle should contain: Boiled or bodied oils or products which dry to a fairly saturated film; oils which dry by semi-polymerization rather than oxidation; oils which dry to a flat rather than a glossy surface. The solid portion of the paint should contain a percentage of pigments which are coarse and tend to form films having rough surfaces; which are inert and do not act as electric conductors; which are either basic or of the chromate type. The painted metal should be coated with sand before drying in order to afford a good bonding surface for the concrete.

Hydraulic Forcing and Miscellaneous Presses is the title of Sectional Catalog No. 92, issued by the Watson-Stillman Co., 50 Church Street, New York. It is an illustrated book of 128 pages, describing the many special types of hydraulic presses made by this company, such as wheel presses, crank pin presses, armature presses, broaching presses, forcing presses, die presses, projectile capping and banding presses, baling presses, briquetting presses, smokeless powder presses, carbon squirting presses, lead presses, crayon presses, etc.

Recent Chemical and Metallurgical Patents

Iron and Steel

Steel Refining.—Mr. W. R. WALKER of the U. S. Steel Corporation, patents the following combination process for steel refining. He introduces molten pig metal into a Bessemer converter and blows it until the silicon and incidentally a large proportion of any manganese which may be in it has been eliminated and the carbon reduced to a definite percentage, preferably to about 0.05 per cent, which percentage can be gaged with accuracy because it is about the percentage contained in the metal at the time when the flame "drops." He then adds to the desiliconized and decarburized metal sufficient carbon to raise its carbon content to a definite percentage, preferably 0.3 per cent. The metal is now enriched in carbon to the same percentage as steel is; it is also deoxidized. It is, in fact, steel but containing an excess of phosphorus, sulphur, etc.

This phosphorus and sulphur is then removed by treating the metal in an electric furnace or an open-hearth furnace. (13,861, Jan. 5, 1915.)

Steel Alloys.—A method of producing silicon-steel, vanadium-steel and other steel alloys is patented by Mr. ARCHIE SMITH, of Leetonia, O., and assigned to the Youngstown Iron and Steel Co. In the ordinary method of making such alloys, the steel is tapped directly into a ladle containing the alloying metal. According to the improved patented process, the steel is tapped first into an intermediate ladle from which, in turn it is tapped into the ladle containing the alloying ingredient. The advantages claimed are the exclusion of slag from the alloy, and the possibility of making use of refining furnaces of any size, so that a large quantity of steel can be refined, charged into an intermediate ladle and then alloyed in smaller charges in the mixing ladles. (1,131,799, Mar. 16, 1915.)

Treating Mill Scale.—A method of reducing the mill scale formed in the manufacture of high-speed steel, is the subject of a patent granted to Mr. FREDERICK M. BECKET, of Niagara Falls, N. Y. By smelting such scale with silicon as a reducing agent, in an electric furnace and in accordance with certain methods disclosed in prior patents, it may be reduced to an alloy having approximately the same composition as that of the steel from which it was derived. Analyses of a mill scale and the alloy obtained therefrom by silicon reduction, are as follows:

	Mill Scale	Reduced Alloy
Tungsten	11.90	15.60
Chromium	2.90	3.40
Vanadium	0.49	0.43

The resulting alloys, however, contain an unusually high percentage of phosphorus, and the product of direct reduction of the scale is low in tungsten. These conditions can be obviated by a preliminary acid treatment, where the major portion of the iron and practically all of the phosphorus are removed. Thus the scale is ground to 8-mesh and treated with sulphuric acid of 1.2 to 1.4 sp. gr., either at normal temperature or at from 50° to 70° C. The residue is washed and smelted with silicon. Up to 75 per cent of the iron can be removed by the acid without material loss of tungsten, and the resulting alloy will contain from 25 per cent to 45 per cent tungsten and be practically free from phosphorus. According to a modification of the invention, the mill scale is subjected to a reducing operation with carbon before acid treatment. The mixture of scale and carbon is heated to about 1000° C. in a retort, and then treated as above described. (1,127,162-3, Feb. 2, 1915.)

Gold and Silver

Agitator.—Fig. 1 illustrates the features of an agitator, patented by Mr. John V. N. Dorr, of Denver, Colo. The apparatus is designed to treat ores by cyanidation, or for the thorough mixture and treatment of finely divided solids in a liquid capable of dissolving a constituent of the solids. The device embodies both air and mechanical agitation, and effectually prevents the accumulation of banks or beds of settled solids within the tank. It consists of a circular tank in which is suspended an upright, hollow, rotatable conduit 3, carrying from its lower extremity two or more radial arms 10, provided with blades or plows 12. Near the upper end of the central conduit are arranged two or more distributing launders 16. The central conduit and attached arms and launders are rotated by means of a worm 8 and wheel 7 above the tank. Compressed air is admitted at the bottom of the conduit through a pipe 24 extending downwardly within the conduit from above, or it may be applied through the bottom of the tank.

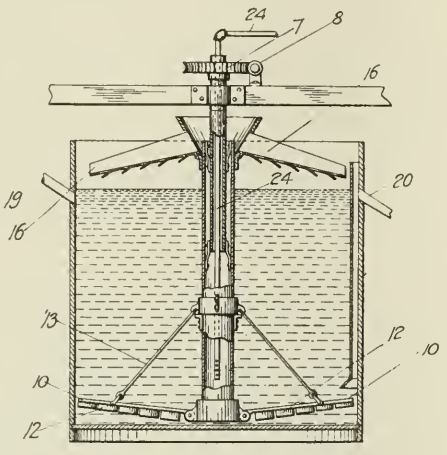


FIG. 1—AGITATOR

In operation the radial arms and plows convey the settled pulp to the central conduit where it is raised by the air-lift to the launders and distributed over the surface of the pulp in the tank. Operation may be continuous through a succession of agitators, the pulp being fed in at one side of the tank, as at 19, and removed at the other side, as at 20. By adjusting the means of discharge, the density of the pulp can be controlled. (1,131,222, March 9, 1915.)

Copper

Use of Sulphur Dioxide in Electrolytic Copper Process. — It has been previously proposed to make use of sulphur dioxide to prevent the harmful action of ferric salts in the electrolysis of impure copper solutions. According to a patent granted to Marcel Perreur-Lloyd, of Boulogne-sur-Seine, France, the method of application has hitherto been defective, and it is the object of his invention to make effective use of this substance as a depolarizer. This he claims to accomplish by bringing about an agitation of the electrolyte. Such agitation can be done either by moving the electrolyte by means of compressed air or by moving the anodes in the electrolyte. The former method has the objection of driving sulphur dioxide out of solution, hence the latter method is preferred. As shown in Fig. 2, one method of moving the anodes is to cause them to rotate in the electrolyte, being moved about a shaft to which they are attached. The cathodes C are stationary. The anodes, which are composed of two parts, A and B, are partly stationary and partly rotatable, A being attached in a stationary manner and B attached to the rotating shaft O. With sufficient agitation of the electrolyte, keeping the sulphur dioxide in solution, it is possible to employ a current of 100 amperes or more per square meter of cathode area and to extract copper from the most impure solutions up to 0.1 per cent and obtain good deposits of copper. It is claimed further that with this apparatus the required electric energy can be reduced to less than one kilowatt hour per kilogram of copper deposited. Sulphuric acid is generated in the course of the process from the sulphur dioxide which, in turn, is cheaply generated from the process of roasting ores. (1,133,059, Mar. 23, 1915.)

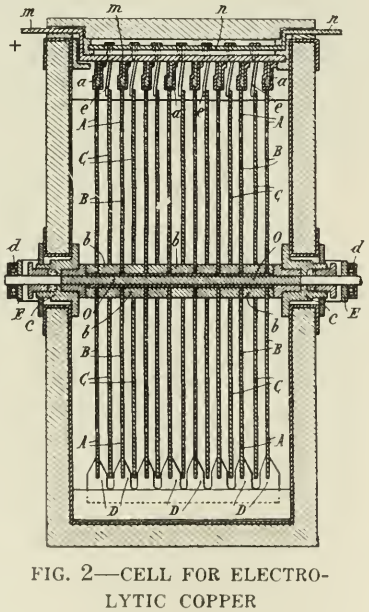


FIG. 2—CELL FOR ELECTROLYTIC COPPER

Notes

Air-Lift Pumping is the title of a bulletin recently issued by the Sullivan Machinery Co. It contains valuable data and information on the subject.

The **Dorr Cyanide Machinery Co.** announce that after May 1, 1915, the address of their New York office will be Room 2843, Whitehall Building, New York City, instead of 30 Church Street, as heretofore.

The Kelly Filter Press Co., Salt Lake City, Utah, has issued a new pamphlet illustrating and describing the Kelly filter press. The company maintains a large testing plant where products can be tested to determine capacity, filtering medium, operating cost and other data.

The **Association of Iron and Steel Electrical Engineers** held a meeting on April 10 at the Seventh Avenue Hotel in Pittsburgh, Pa., a paper by Mr. A. W. Soderberg, of the Carnegie Steel Company, on "Apprenticeship and Educational Work in the Iron and Steel Industry" being on the program. Another meeting was held on May 1, when Mr. R. S. Wile, president of the Wile Electric Furnace Company, presented a paper on the electric furnace and the melting of alloys in the electric furnace.

The Liberty Bell mine, Telluride, held its first annual "Safety First Dinner" on April 8, "to celebrate a year without a fatal accident and with fewer serious accidents; to pledge ourselves to better care in future." This is a new and effective method of bringing the "safety first" idea prominently before the employes of a company. The dinner was followed by five-minute talks by General Manager Charles A. Chase, Mill Superintendent W. E. Tracy and others. The evening was enlivened by "safety first" verses sung to the tune "Tipperary."

Water Meter.—The Yarnall-Waring Co., Chestnut Hill, Philadelphia, has just received orders for four Lea V-notch recording liquid meters in combination with Webster feed-water heaters aggregating 1,125,000 lb. per hour capacity, from the E. I. duPont De-Nemours Powder Co., Wilmington, Del., following the original installation of the Lea system by them two years ago. They also report an order for a 275,000-lb. per hour capacity Lea V-notch recording liquid meter for the new power plant of the Victor Talking Machine Co., Camden, N. J.

Fuel-Supply Contracts and the Progress of More Scientific Methods of Purchase and Control in America and Europe

BY JOHN B. C. KERSHAW

That the application of scientific methods for determining the sale and purchase value of fuel is advancing in favor, is proved by the growing literature of the subject, and by the increasing tendency of power engineers in the leading industrial countries, to demand guarantees from the colliery companies, or from the coal dealers and "middlemen," that the fuel shall yield on test a minimum number of calories, or shall contain less than a definite maximum percentage of sulphur and ash.

These newer methods of purchase and control have obtained their widest application in America, a result due partly to the fact that the American Government has taken up vigorously the system of purchasing fuel on a heat-unit basis, and partly to the greater readiness of American business men to give science its proper place in the control of industrial and manufacturing operations.

In Europe the necessary incentive to adopt more scientific methods has been supplied by the advanced labor legislation of recent years, and by the striking rise in the cost of coal mining in the leading industrial countries. The additional financial burdens placed upon the colliery owners have, in fact, rendered the use of scientific methods for checking the quality and price of fuel imperative, for not only has the price of fuel been increased by 20 per cent to 30 per cent within the last few years, but the quality has at the same time deteriorated, and every large fuel-user knows only too well that he is *now paying more for a worse fuel than ten years ago.*

The (British) Eight-Hours-Day Act has been the chief factor in causing this deterioration in the quality of the fuel mined, a deterioration which is most marked in the case of the slack and small coal sold in large quantities for steam-raising purposes. In order that the miner may produce his daily quota of output he has to work with less care than formerly, and a much larger proportion of shale and dirt is now brought to the surface with the coal than was the case ten years ago.

The proportion of smalls in every 100 tons of coal raised has also increased enormously since the Mines Eight-Hours Act came into force. The writer of this article has tested quite recently a large delivery of slack sold by a well-known Lancashire colliery company for steam-raising purposes which gave the following results when graded in the laboratory:

Slack left on ¼-in. mesh sieve..... 48 per cent.
Fine slack which passed through ¼-in. mesh sieve ..... 52 per cent.

The latter portion of the slack was again graded into two portions by use of a 1/12-in. mesh sieve and it was found that nearly one-half of this portion, or 24.3 per cent of the original weight of slack, was composed of fine dust that passed easily through a 1/12-in. mesh sieve. Separate ash tests of these three grades of slack were then made and the test results are sufficiently interesting to be given here:

Slack left on ¼-in. mesh sieve.... 11.15 per cent ash.
Fine slack, between ¼-in. and 1/12-in. mesh ..... 19.20 per cent ash.
Dust under 1/12-in. mesh..... 29.60 per cent ash.

Nearly 25 tons of every 100 tons of this slack as delivered was therefore practically valueless as a fuel in any ordinary boiler furnace, and in this particular case it only served to clog up the air passages of the firebars and to prevent proper combustion of the remaining 75 per cent of the fuel. To charge $3.25 per ton for such a slack was a gross imposition upon the fuel-user. Instances of a similar kind could be given in large numbers, but enough has been said to prove that during the past ten years the quality of fuel has deteriorated enormously while the price has increased, and that the need for the application of scientific methods of controlling the quality and price of fuel was never more urgent than at the present time.

In this article details will be given of the methods in use in Germany, Switzerland, the United Kingdom and America for sampling and testing fuel in transit, or when discharging at the consumer's works. Some examples of forms of contracts, in which the price paid for the fuel is made dependent either upon the calorific value, or upon the percentage of ash will also be given.

Germany.—The information relating to German methods has been obtained from Dr. Aufhäuser, head of the Thermochemische Prüfungs-und Versuchs-Anstalt in Hamburg. The fuel testing for the members of the *Hamburg Verein fur Feuerungsbetrieb und Rauchbekämpfung* is carried out at this laboratory, and the last annual report of the above society contains the results of many hundreds of tests of samples of English and German coals, which have been made in Dr. Aufhäuser's fuel-testing laboratory. A large number of members of the *Verein für Feuerungsbetrieb* are now having their supplies of fuel sampled and tested regularly, the usual plan being to take separate samples of each 50 tons of coal as delivered, and to have these samples tested for moisture and ash, and also for calorific value, in a Berthelot-Mahler bomb-form of calorimeter. In some cases the purchasers of the fuel have been able to arrange for contracts with the "middlemen," or colliery agents, in which the price paid varies with the monthly average of these calorimetric tests, the basis of the contract being a fixed price for 100,000 calories. In other words heat units and not coal are bought and sold.

In the majority of instances at Hamburg, however, only two limits are inserted in the contract, namely, a *minimum calorific value* and a *maximum percentage of ash.* The seller of the fuel then contracts to deliver a fuel which shall not fall below a certain stated calorific value, or contain above a certain stated percentage of ash, and if any delivery of fuel is found which does not fulfil these conditions of sale it is either returned to the seller or an allowance is made on the price.

Average tests of the monthly deliveries are taken in deciding upon the value of the fuel and slight variations up to 1 or 2 per cent are generally overlooked. Very bad or dirty samples are quickly detected by the wide deviation of the test results from the average of the deliveries, and the tests of such camples *are not included in the average*, unless the sampler is convinced they represent fairly the deliveries on the particular occasion when they were taken.

Although the colliery companies and "middlemen" prefer this form of contract to the former one, it is really the more rigorous of the two, for it contains no possibility of the price being increased, when the fuel actually supplied is rather better than that contracted for. The simpler form of contract is, however, preferred; and not only in Hamburg but also in many other industrial centers of Germany the supplies of fuel are now being purchased under what is practically a chemical guarantee of quality. Over 1000 samples of fuel were tested at Hamburg in 1909 and the work of Dr. Aufhäuser's laboratory has increased greatly in the four years that have elapsed since that return was published.

Switzerland.—The facts and figures relating to the progress of fuel sampling and testing in Switzerland have been obtained from Prof. E. J. Constam, director of the federal fuel-testing laboratory at Zürich. The erection and equipment of this laboratory was one result of the purchase of the Swiss railways by the state in 1902 and of the fact that all the fuel required for working the railways was purchased in France or Germany, generally in the form of briquettes.

The laboratory is an annex of the Zürich Polytechnic and is really an extension of the old thermo-chemical laboratory, the extensions and equipment costing about $10,000 and having been completed in 1907. In the year 1908 (the first of its existence) over 3300 samples of fuel-briquettes and coal were tested in this laboratory, and the latest available figures show that this has been increased to 5860 in 1912. The laboratory examines fuel for private firms and indivduals, as well as for the state railways, and from time to time the results of its investigations are published in the form of a report.

As the value of briquettes depends largely upon their ability to stand handling without falling to pieces, an important test at this federal laboratory is that for "cohesion." This test is carried out as follows: Fifty kilograms of the briquettes are put into the drum of the cohesion testing machine in ½ kg lumps. The machine is set in motion and, after making fifty turns in two minutes, the contents is emptied onto the gridiron and shaken. What remains behind is weighed. This is expressed as a percentage of the weight used and gives the cohesion value, which in the case of good briquettes should not be less than 55 per cent.

The large number of tests carried out at this state-aided laboratory has had good results in Switzerland for it has tended to enlighten the consumers as to the relative economic values of the fuels they have been importing from the various countries, and has assisted in their classification according to heating power.

The director of the federal fuel-testing laboratory, Dr. Constam, is a firm believer in the use of the thermal value of a fuel as the basis of the fuel-contract, and he is doing all he can to get this system of purchase adopted in Switzerland.

Both the coal producers and the consumers are stated to be satisfied with the methods of fuel sampling and testing adopted at the Zürich laboratory. The results of the tests are compiled monthly and are communicated to both the sellers and buyers of the fuel. In the case of briquetted fuel the settlement is effected by adding to or deducting from the price a proportionate sum for every 90 B.t.u. by which the average monthly calorific value of the fuel actually delivered differs from the standard calorific value inserted in the contract.

The United Kingdom.—Although a very large amount of fuel-testing is being carried on in the United Kingdom at the present time in the laboratories of technical colleges and universities, of independent experts, and of works and factories, it is not easy to give an exact record of what is being done since the English manufacturer and works-manager is extremely unready to make his methods of control and management known, even when these contain little that is novel or of patentable value. It is certain, however, that in a large number of works and factories where fuel is an important item in the costs of production the deliveries of fuel are regularly and systematically sampled, and that these samples are tested either in the laboratory attached to the works or are sent to some independent institution or analyst for examination.

With regard to the form of the fuel-contracts used in the United Kingdom little progress has been made yet in persuading the colliery companies or the coal dealers to sell coal on a sliding scale basis, *i. e.*, to sell calories or heat-units in place of tons of coal.

The majority of fuel contracts are based, however, on the system of guaranteeing a certain definite standard of quality expressed in British thermal units and in percentages of moisture and ash. Should the coal actually supplied not come up to this standard of quality the delivery may be rejected. This form of contract suffers from the grave defect that in nine cases out of ten the fuel is discharged and is partly or wholly used before the deficiency in heat units or high percentages of moisture and ash are discovered. The rejection of the fuel is, therefore, a course which can rarely be adopted, and as the colliery company is protected in this manner from the operation of the clause, the adjustment of price, which ought to follow the delivery of bad fuel, seldom occurs.

The systematic sampling and testing of the fuel which is going on, however, has some effect in keeping up the quality of the fuel delivered. A contract with a clause defining the quality of the fuel purchased in B.t.u. and setting limits to the allowable percentages of moisture and ash, is certainly an advance upon the form of contract in use fifteen or even ten years ago, when only the mine and seam of coal were named in the clause specifying the quality.

Some practical examples of the forms of contract that have been tried or are now in force in the United Kingdom are given below. These are drawn chiefly from the electrical supply companies, since the engineers of these undertakings are quite ready to answer inquiries, and the writer is most in touch with what is being done in this branch of the engineering industry.

A. A Large Municipal Electrical Supply Undertaking in Scotland.—The chief engineer reports that samples are taken daily of all the coal, a small scoopful of coal being taken by the check weighman from each ton-load delivered. These small samples are stored in a clean receptable until the barge or wagon is empty. The sample is then reduced by crushing and quartering to one of 3 lb. and this is forwarded in a sealed tin to the testing laboratory of the electricity department. The contents of the tin are there crushed and still further reduced in bulk in the usual manner and the calorific value of the sample is finally determined in the bomb type of calorimeter.

If the tests show that the fuel being delivered is below the standard set for the particular pit from which it is shipped complaint is immediately made and the cause of the deterioration in quality is usually found to be *careless mining and picking of the coal.* By this means the engineer of this works reports that they have obtained a thorough working knowledge of the relative values of all the fuels mined within a practical distance of the generating station and when offers of coal are made they can bring all prices down to a common calorific basis by use of their past test records for each pit. Although the contract is not based on heat units they are able to bring the contract price into close agreement with the real calorific value of the fuel.

B. A Large Municipal Electrical Supply Undertaking in the Midlands.—The chief engineer and general manager reports that the fuel is sampled and tested daily. Samples are taken from the rotary filler supplying a conveyor at intervals during the unloading of each boat, the coal in this case being delivered by canal. Each day's samples are mixed and are quartered down into two lots of convenient size. One of these is tested for calorific value, ash and moisture daily, the other portion is put with the previous day's sample in order to make up the weekly average sample of fuel.

The Contract stipulates for a certain calorific value

and ash percentage but the price is not dependent upon the quality. This latter must, however, be maintained or the fuel can be rejected, and if not rejected a claim can be made for a reduction in price based on the average figures of tests taken over the period in question.

C. A Large Municipal Electrical Supply Works in the North of England.—The borough electrical engineer reports that tenders are invited for fuel to a specification which records the minimum calorific value of the fuel and also the maximum percentage of ash. When the tenders are received certain fuels are picked out for testing purposes. A sample lot of 100 tons is asked for (this is equal to one day's supply) and the whole of the works is then run on this sample lot, the weight and cost of fuel per unit generated and the percentage of ash made being carefully noted. In addition to this practical test a laboratory test is made from a sample sent to an analytical chemist. The contract is placed with the firm whose sample of fuel shows the best practical results per unit generated, but regular analytical tests of the fuel are made during the period for which the contract runs and a clause is inserted in it giving power of cancelling the contract in the event of the fuel not coming up to the guaranteed calorific value. The laboratory tests are therefore used in this case solely to check the quality of the fuel delivered.

D. A Large Cotton-Spinning Company with a Mill in the Manchester District.—This company managed to obtain in 1908 a contract with a Lancashire colliery company on the sliding-scale basis but after a two years' trial the contract was not renewed. This non-renewal was due to the objection of the colliery company to the terms of the contract and to their refusal to be bound by them, even when the fuel supplied was better than that contracted for and the price variation was in their own favor.

While this contract was running two carefully prepared average samples were tested per month by an independent analyst. These samples showed a striking uniformity in ash contents and calorific value, the variation from the calorific value of the sample upon which the contract was based being well within 5 per cent for the whole of the period. This uniformity in the heat-value of the coal actually delivered was, no doubt, largely due to the knowledge that the coal was being regularly sampled and tested at the consumer's works. The consumers recognized this fact themselves, and stated in a letter to the author that "we are greatly in favor of the system of purchase upon calorific units. Since our contract of December, 1908, when we began the new system, we have had a much more uniform fuel supplied to us, which is all we aimed at."

E. A Flour-Milling Company with Several Mills in Southwest Lancashire.—This company, like that cited above, found a firm of colliery proprietors willing to close a contract on the sliding-scale basis.

The experience of the second firm, however, has been rather different from that of the first, since marked variations occurred in the quality of the fuel supplied, and in consequence there were considerable reductions made in the price paid for the fuel. It is noteworthy that the largest increases in ash and corresponding decline in calorific value occurred during the second half of the year 1909, although the coal merchants declared they were supplying exactly the same fuel as in the earlier months. This falling-off in the quality of the fuel contracted for lends support to the assertion that the operation of the mines eight-hour act is affecting the quality of the small coal raised and sold in certain mining districts.

In this case, also, the sliding-scale arrangement ceased at the end of 1910 owing to a change of management at the mill and the appointment of a manager who did not believe in the value of fuel-testing.

In concluding this account of the progress of the movement for the more scientific control of fuel supplies in England, reference may be made to a standard coal specification for the purchase of coal by electricity works. This specification was drawn up by a committee representing the principal London firms of coal contractors on the one hand and the Associated Municipal Electrical Engineers of Greater London on the other.

There are two model specifications, the first being for a coal of a particular description or "named" coal; while the second is for a coal guaranteed to possess certain definite physical qualities.

The principal feature of this latter specification for "guaranteed coal" are as follows:

The tenderer shall set out in his details the classes of coal for which he is tendering corresponding with the classes referred to in the table of standards.

Testing—(*a.*) A representative sample shall be taken on delivery from each or any consignment and shall be divided and sealed in three air-tight vessels. The contractor shall be at liberty to be represented when the sample is taken, and shall be entitled to one portion thereof; but he shall have no opportunity at a later date of objecting to the manner in which the coal has been sampled.

(*b.*) Samples taken in the manner defined shall be taken from each consignment and tested by the purchaser, or in the event of a dispute by a competent expert, who shall be approved from time to time by the purchases and whose fees shall be paid by the contractor if the purchaser's test is confirmed. The tenderer is invited to set out in the tender's details, the names of three experts either of whom he is agreeable shall be employed. A table of standards is then given for application in connection with guaranteed coals. As regards the methods of testing the fuel the following conditions are laid down:

British thermal units shall be ascertained on coal dried at 220 deg. Fahr. for an hour by means of a Mahler-bomb calorimeter. Moisture shall be represented by the total loss in weight of the coal delivered after air-drying and exposing to a temperature of 220 deg. Fahr. for one hour. The percentage of sulphur shall be based on the analysis of the coal "as received" and must not exceed 2 per cent. The sieves used for determining the percentages of "small" shall be of square mesh with openings in the clear to the sizes given.

America.—As already stated earlier in this article the United States Government has given a strong lead in America to the scientific control of fuel supplies by purchasing a large proportion of the coal required for the navy and other state departments on a B.t.u. or strictly specified basis. As regards the naval requirements the fuel is purchased on a B.t.u. basis, a premium being paid for all coal showing more than 15,000 B.t.u. in the dry state, and no wet coal being accepted. The balance of the government's annual coal purchases is bought on a pro rata as received B.t.u. basis and the seller is also penalized to the extent of from two cents to thirty-five cents per ton for variation in ash rising from 3 per cent to 9 per cent above the guaranteed amount, 2 per cent above the guarantee being allowed to pass without fine. The method of sampling and of calculating the heat-value is as follows:

In all cases where practicable the coal is sampled during its discharge into the building where used. The sample selected in no case is less than 100 lb. and it must be reduced by repeated crushings and quarterings to the small amount required for testing by the treas-

ury department. The method of analysis and of calorific valuation is that drawn up by the American Chemical Society.

Payment is made upon the basis of the price named in the proposal for the coal specified by the seller, correction being made for the variation in ash and heating value. For example, if the coal contains 2 per cent more or less B.t.u. than the standard named in the specification the price is increased or decreased in the same proportion.

The price is also corrected for the percentage of ash, and for all coal which contains less ash than the standard named in the specification a premium of 1 cent per ton is paid for each 1 per cent of ash. An increase of 2 per cent of ash over the standard named in the specification, on the other hand, is not weighted with a penalty, but above this limit a deduction is made from the price paid for the coal. The coal is to be weighed as delivered, and as payment is made upon this delivery weight the calorific test is made upon the coal containing whatever moisture may be present at the time.

With regard to other methods or systems of purchase in use in America, the Fuel Engineering Company, of Chicago, was founded in 1908 as an independent sampling and testing organization with a large number of clients who purchased fuel on a B.t.u. basis and handed over all the scientific work required in connection with this method of purchase to the officers of the company. The company published a monthly test sheet for circulation among its clients giving details of all the tests made during the previous month. Much valuable information concerning the comparative value and price of the fuels marketed in Chicago thus became the common property of all who were having regular tests made by this organization of their fuel deliveries, and each consumer found out quickly if he was obtaining a good return for his expenditure upon fuel. The specification and method of regulating the price by the quality used by the Fuel Engineering Company, of Chicago, was more complicated than that used by the United States Government departments and was based upon what was called the "contract guarantee," or number of B.t.u. which was obtainable for 1d. (2 cents) from the trial sample of the fuel.

The Interborough Rapid Transit Company is an electric tramway company which consumes annually 360,000 tons of a bituminous "run of the mine" coal. This is purchased upon a B.t.u. basis—with limiting values of 9 per cent for ash and of 1.5 per cent for sulphur. Variations above or below these figures are subjected to deductions or premiums as the case demands.

The coal for the Panama Canal constructional works, which amounted to 650,000 tons per annum, was also purchased on a B.t.u. basis of 14,600 as received, with deductions for variations below this limit.

The Department of Water, Gas and Electricity Supply for New York City uses a very large quantity of coal per annum and the system of fuel control employed is considered by its officers to be an improvement upon the system used by the United States Government departments. According to the description of the system given in *Power* by F. R. Hutton and J. L. Pulz, before drawing up definite specifications a careful investigation is first made of the character of the various coals furnished in the buyer's area, and from these results a diagram is plotted representing the variations in moisture, ash, volatile matter, sulphur and combustible matter. Any coal falling within the limits considered desirable are put on the list of eligibles as to quality. Coals lying outside these limits and below them are penalized with respect to weight, but not as to price, so that the buyer should not buy water or incombustible mineral matter and pay for them at the rate agreed on for good coal. The research carried out on these lines by the company's staff developed the relation that each percentage of ash in the coal besides displacing 1 per cent of combustible matter has a retarding effect (varying with the quality of the coal) equivalent to the withdrawal of between 145 and 155 B.t.u. or an average of 150 B.t.u. With this as a basis, a formula was evolved applicable both to anthracite and bituminous coal in the following form:

$$\text{Corrected tonnage} = \text{tonnage delivered} \times \frac{\text{B.t.u. per lb. as delivered} - 150 \text{ B.t.u.} \times \text{excess percentage of ash}}{\text{B.t.u. per lb. as specified in standard analysis}}$$

For practical purposes the formula can be simplified by using a direct percentage relation whereby 1 per cent in weight shall be deducted for each 100 B.t.u. and an additional 1 per cent for each percentage of ash. This can be equally well applied when it is desired to give a bonus.

The weight of the coal after correction for moisture is then reduced at the rate of 1 per cent for each percentage of ash in excess of that permitted by the standard and the gross dry weight after correction for moisture is reduced at the rate of 1 per cent for each 100 B.t.u. below the standard heating value. The gross dry weight is also corrected at the rate of 5 per cent for each 1 per cent. of volatile sulphur in excess of the standard. These corrections are then aggregated and deducted as a whole, payment being made only for the balance of the gross weight at the price bid per unit furnished, delivered and stored and trimmed (if so specified in the schedule).

These examples will show that purchases on a B.t.u. basis is the rule rather than the exception with large fuel users in the United States and that there are many different ways of carrying this out.

As proof of the interest taken in the subject of fuel sampling and testing in America, the publications of the Bureau of Mines at Washington may be referred to. The following list of bulletins is by no means complete, but it shows how well the subject has been covered.

1908. Bulletin 339.—The Purchase of Coal under Government and Commercial Specifications, on the Basis of its Heating Value.
Bulletin 362.—Mine Sampling, and Chemical Analysis of Coals Tested at the U. S. Fuel-Testing Plant, Norfolk, Va.
1909. Bulletin 378.—Results of Purchasing Coal under Government Specifications. 1907-1908.
1910. Bulletin 428.—Results of Purchasing Coal under Government Specifications. 1908-1909.
Bulletin 27.—Tests of Coal and Briquettes as Fuel for House-heating Boilers. By D. T. Randall; 44 pp.; 3 pls.; 2 figs.
Bulletin 28.—Experimental Work Conducted in the Chemical Laboratory of the United State Fuel-testing Plant at St. Louis, Mo., January 1, 1905 to July 31, 1906. By N. W. Lord; 51 pp.
1910. Bulletin 41.—Government Coal Purchases Under Specifications with Analysis for the Fiscal Year 1909-1910. By G. S. Pope, with a Chapter on the Fuel-Inspection Laboratory of the Bureau of Mines. By J. D. Davis, 1912; 97 pp.; 3 pls.
Technical Paper 1.—The Sampling of Coal in the Mine. By J. A. Holmes, 1911; 18 pp.: 1 fig.
Technical Paper 8.—Methods of Analyzing Coal and Coke. By F. M. Stanton and A. C. Fieldner, 1912; 21 pp.; 5 figs.
Technical Paper 26.—Methods of Determining the Sulphur Content of Fuels, Especially Petroleum Products. By I. C. Allen and I. W. Robertson, 1912; 13 pp.; 1 fig.

The **Cusi Mining Company** of Chihuahua, Mexico, has recently installed a 5-ft. by 16-ft. adjustable quick-discharge tube mill of Chalmers & Williams.

Is Duplexing Slated for Assassination?

BY JOSEPH I. PEYTON

Duplexing of late years has been the subject of much criticism, especially in regard to the quality of the product, by various engineers and users of rail steel.

It has only recently been brought to light that one of the main causes of duplex steel not comparing favorably with that of the straight open-hearth practice was due to the fact that in the converting department, where the molten metal is blown, the manganese originally in the blast furnace or mixer metal was nearly all eliminated, *i.e.*, most of the manganese went into the slag as manganese sulphide and manganese oxide, while some volatilized, passing out of the converter as a gaseous product. Then when the blown metal was transferred to the open-hearth furnace for further refining, there was naturally a shortage in manganese content, which is so necessary in the open-hearth furnace, to assist in reducing sulphur from the steel, and at the same time preventing the occurrence of overoxidation of the metal.

To obtain a good quality of steel, a good quality of slag is absolutely essential as well, and to obtain this a sufficient amount of manganese should be present. In duplexing, formerly, there was no addition to the manganese content of the blown metal, other than the amount contained in the direct mixer metal, which is charged into the open-hearth furnace for the purpose of raising the carbon content of the bath, until just before tapping or directly afterwards, thus the benefit of having a sufficient amount of manganese present throughout the operation was lost. The present practice, however, of adding manganese to the blown metal differs in different plants, largely due to conditions.

Some use a high-manganese mixer metal and add a small quantity to each ladle of blown metal before it is transferred to the open-hearth furnace. Another method is to use sufficient steel scrap containing enough manganese to give the bath the desired content. Others use an ore with a high manganese content as a part of the open-hearth furnace charge or in the working of the heat, and where conditions are not so favorable ferromanganese or spiegeleisen is charged, preferably after part of the molten charge has been made in the open-hearth furnace. Since the adoption of this practice duplex steel has rolled as well as the straight open-hearth steel, proving that duplex steel has the quality.

Another improvement in duplexing of vast importance, not so much in improving the quality of steel, but in saving time in working the heats, is the elimination of the Bessemer slag from the open-hearth furnace. Bessemer slag is most variable in volume, due entirely to conditions, and contains considerable quantities of silicon dioxide, which when entering the open-hearth furnace changes the constituency of the slag of the furnace, making it necessary for additional lime to flux the silicon dioxide of the Bessemer slag and on account of the fluctuating volume of highly silicious slag from the Bessemer, it renders it difficult for metallurgical calculation to take care of it in the initial charging of the furnace. However, the recent methods of straining blown metal through either a stoppered ladle or one of the cupola-tap type, leaving the slag in the ladle, has helped the situation to a marked degree, both as to the time and ease on the furnace linings.

No doubt many consumers of steel have had the impression that duplex steel on account of its being made much faster and with fewer units involved than in straight open-hearth practice was a moneymaker for the manufacturer, but as a matter of fact, it costs the manufacturer more to make duplex steel than it does to make straight open-hearth steel, except when the price of scrap is excessive. The metallic loss in the Bessemer converter department is very high as compared to the metallic loss in the straight open-hearth process, and the metallic loss in a duplex basic Bessemer is about double the metallic loss in the duplex acid Bessemer. It is this huge metallic loss in the Bessemer department that makes the cost greater to the manufacturer.

To duplex economically the units must be large and in close proximity, which means a minimum waste and a minimum labor cost. So many of the plants engaged in duplexing work under distressing conditions as to cost and metallic loss, which is due to the size of the units and their arrangement principally. The most efficient duplex mill in existence is located at Steelton, Pennsylvania, and it should produce results on duplexing well worth knowing.

Several prominent metallurgical men who know that duplex steel possesses quality, have said that if the discard in the ingot could be reduced to 5 per cent, duplexing would be absolutely necessary on account of the high price that scrap would then assume.

INGOT MOLD WITH HEAT-INSULATING VACUUM CHAMBER

It is a fact well known to all metallurgists that something to prevent the enormous waste in shearing to obtain sound steel, i.e., steel free from piping and segregation, would be most welcome to the steel industry. For that reason many men have come forth with suggestions, methods, processes and inventions for the producing of sound ingots. Most of them, however, are impractical and a few cost too much per ton of steel produced to ever be of any commercial value to the manufacturers of the cheaper grades of steel.

The few methods in use find a market only where high-grade, high-priced steels are manufactured, which steel can afford a considerable tariff for the betterment of the product. Three methods in use are the Harmet or pressure process, which is very expensive, and is only used on high-grade steels, such as high-grade marine shafting, etc., the a[illegible]-piping thermit method, which costs 35 cents per ton of steel produced, and the Hadfield method, with a refractory sand ring in the molds head, using charcoal to cover the ingot top just after the teeming of the molten metal into the ingot mold with a forced gas flame playing thereon, which method costs 25 cents per ton of steel produced for the sand ring and claims to cut the discard to as low as 8 per cent. Even this method is hardly to be considered in connection with the cheap steels, for aside from the cost, it must require considerable labor and time to equip the molds each time before the teeming of the molten metal into them.

For that reason there has been developed a new type of ingot mold, upon which patents have been issued, which is cheap, practical and economical. It is cheap from the standpoint that there is practically only one cost (the initial cost) and when considering the average life of an ingot mold, it cuts the cost to a matter of only a few cents per ton of steel produced. It is practical because these molds are as ever ready as the molds in common use to-day. It is economical from the standpoint of a sounder ingot, which should offset the cost thereof many times. It has within the mold itself the most efficient heat insulator known, that is, *a vacuum* chamber, as shown in the accompanying figure. It is known as "Peyton-Hitt vacuum chamber ingot mold."

Instrument Exhibit at San Francisco

The Bristol Company, Waterbury, Conn., have a large exhibit of their extensive lines of recording instruments for pressure, vacuum, liquid level, differential pressure, temperature, electricity, time, motion, speed humidity, etc. at the Panama-Pacific International Exposition, at San Francisco. This exhibit (Fig. 1) is located in the

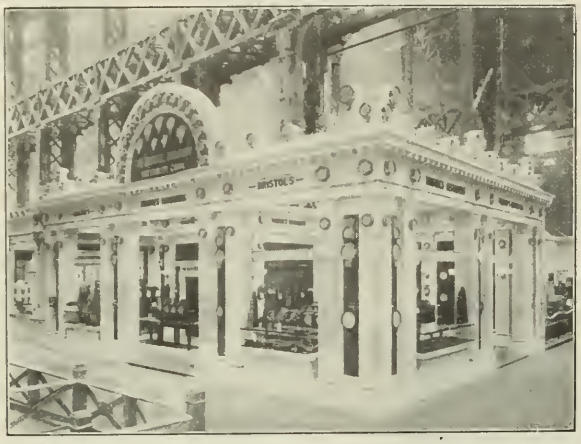


FIG. 1—INSTRUMENT EXHIBIT

Palace of Machinery in section 22. The decoration of the superstructure of the booth are actual models of Bristol recording instruments.

On the lower part of the outside columns of the booth actual working models of Bristol Instruments are exhibited in operation, producing records of atmospheric temperature, the level of the tide in the bay, over a distance of several hundred feet, electrically, also records of conditions on the electrical circuits of the Palace of Machinery, including volts and cycles, or frequency,

FIG. 2—INSTRUMENT EXHIBIT

record of the water pressure in the mains of the Palace of Machinery, and records of the operation of a series of signal switches provided for the visitor to manipulate at will.

Inside the booth, an interior view of which is shown in Fig. 2, more than 100 complete working models of the Bristol recording instruments are mounted on walls and tables, and of these instruments quite a number are arranged in the form of demonstration outfits which can be operated by hand by the visitor.

For instance, a hand-operated generator is provided for lighting a series of lamps and mounted with it is a Bristol recording voltmeter, an ammeter, and a wattmeter, recording simultaneously the voltage and the amperage as well as the wattage on these lamp circuits.

Another interesting demonstration outfit is a pair of the new Bristol long-distance electric thermometers by means of which the visitor is shown how the temperature of his own hand could be indicated automatically on an instrument 50 miles away from the point at which the temperature is measured.

The instruments in many demonstration outfits are shown with glass fronts, or without covers, making it possible for the visitor to see the simple internal construction, and to study the principles of operation.

Electric Steel in Germany and Austria

The following latest figures on the use of the electric furnace for steel refining and reduction and production in Germany and Austria during 1914 should be of considerable interest.

The total production of electric steel in **Germany** in 1914 was 89,336 tons. Of these 44,080 tons or 49.34 per cent were produced in furnaces of the three types controlled by Siemens & Halske, as follows: 34,393 tons or 38.50 per cent in induction furnaces, 7437 tons or 8.32 per cent in Girod furnaces, and 2250 tons or 2.52 per cent in radiation furnaces.

In 1914 there were twenty electric steel plants in operation in Germany, not including electric furnaces for melting ferromanganese. Of these twenty plants ten used furnaces controlled by Siemens & Halske, as follows: Six plants have only induction furnaces, two have induction furnaces and Girod furnaces, one is equipped with only Girod furnaces, and one with radiation furnaces only.

The other ten electric steel plants used furnaces not controlled by Siemens & Halske, as follows: Seven use Heroult furnaces, two Nathusins furnaces, and one Keller furnaces.

Plants which contemplate building new electric furnaces are not included in the above figures.

Of all the above-mentioned twenty electric-furnace plants eight use the electric furnace for making high-grade electric steel to supplant crucible steel. Of these plants four use only induction furnaces, two induction furnaces and Girod furnaces, and two Heroult furnaces.

The total amount of crucible steel and electric steel produced in Germany in 1914 was 184,432 tons, of which 95,096 tons or 51.6 per cent were crucible steel and 89,336 tons or 48.4 per cent electric steel. *Electric steel has therefore now reached practically the same commercial importance as crucible steel in Germany.*

Twelve plants using electric furnaces for melting *ferromanganese* were in operation in Germany in 1914. Six of these plants used Siemens & Halske furnaces namely, induction furnaces (four plants), Rombach furnaces (one plant), and Girod furnaces (one plant). In the other six plants Heroult furnaces are used in three plants, the Nathusins furnace in one plant and the Keller furnace in two plants.

The production of electric steel in **Austria-Hungary** in 1914 was 19,844 tons. Of this amount 9037 tons, or 45.54 per cent, were produced in induction furnaces. The production of electric steel made in Girod furnaces cannot be specified as these furnaces are also used in plants operated by the Government. The production of electric steel made in Siemens & Halske furnaces is, however, over 50 per cent of the total production.

The total amount of crucible steel and electric steel made in Austria-Hungary in 1914 was 37,401 tons, of which 19,844 tons or 53.1 per cent were electric steel and 17,557 tons or 46.9 per cent were crucible steel. That is, *Austria-Hungary now produces more electric steel than crucible steel.*

An Important Advance in Gas Producer Efficiency

The "Producer-Gas Machine," built by the Morgan Construction Company of Worcester, Mass., represents a radically new departure in gas producer design, and the results obtained thereby mean a very important

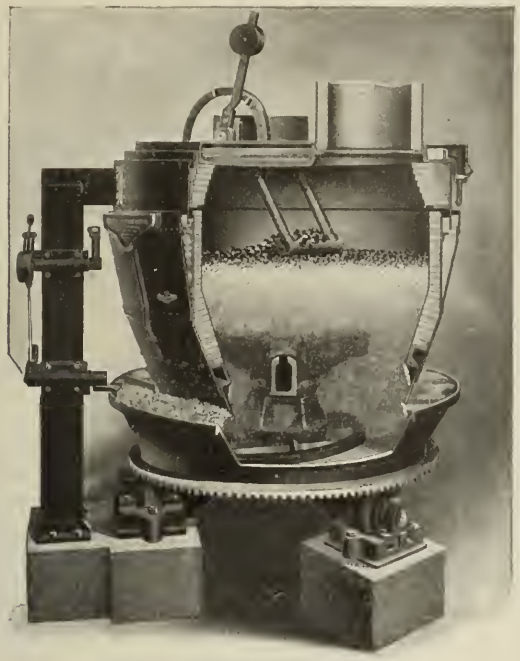


FIG. 1—GAS PRODUCER MACHINE

advance in efficiency of operation. Heretofore it has been an axiom of gas producer design that it is necessary to poke or otherwise break up the fuel bed. The Morgan producer-gas machine is based upon the opposite principle—namely, that the fire must not be disturbed, that it is far better to leave it alone, provided certain essential conditions are fulfilled. These conditions are that the coal be properly spread and the surface be properly leveled, that the ash be removed without producing an uneven fuel bed, that small quantities of coal be regularly and continuously fed to the producer, and that all these functions be performed by continuous mechanical means without hand labor.

The reason for the effectiveness of leaving the fire alone is that every disturbance of the body of the fuel causes variations of density which create local hot places and, in consequence, poor gas and clinkers. To have a uniform, even, quiet fuel bed, two conditions must be fulfilled. First, the top surface must be continually levelled; this is done, as shown in the illustrations, by the leveller which floats on the fuel, permits any practicable variation in height, and is quickly and easily replaced through the top. Second, the removal of the ash must be carried out in such a way as not to make the fuel bed uneven. For this reason, it is a mistake to rely upon sweeping the ash off the edge of the ash support. In the Morgan producer-gas machine the entire bottom of the ash pan is swept by a spiral-shaped bar or plow, the result being a uniform settling of the ash over the entire area. The plow is simply held stationary by the setting of a lever, while the machine makes one complete revolution, which requires fifteen minutes, and is usually sufficient to discharge the ash made in twelve hours. The release is automatic.

Regular continuous feeding of small quantities of coal requires the abolition of manual charging. The feeding device receives the coal from the bin and charges it in small and uniform quantities at frequent intervals *without manual action*. A result of the development of this feeder, acting together with the coal leveler and ash plow, is that one man can tend a battery of six machines gasifying four times as much coal as is possible for one man in any previous construction.

While practically all known types of mechanical gas producers, having a gas-making surface of 10 feet diameter, operate at an average rate of not over 1600 to 1700 lbs. of coal per hour while yielding gas averaging about 145 B.T.U. per cubic foot from Pittsburgh coal, the 10-foot Morgan producer-gas machine converts 3000 lbs. of the same coal per hour, into gas yielding 178 B.T.U. per cubic foot. This is an advantage of over 50 per cent in capacity, combined with 20 per cent advantage in quality.

Before giving further results from actual practice, a few words should be said concerning some minor, though important details of design. The even distribution of the blast over the entire gas-making area would

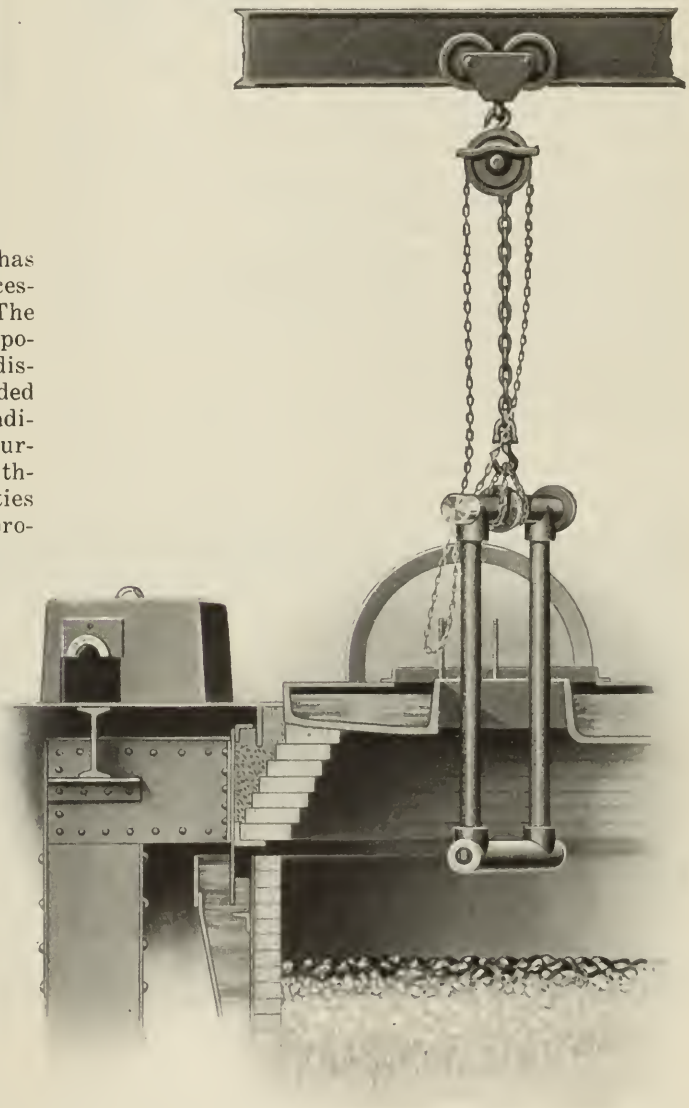


FIG. 2—REMOVING THE FUEL LEVELLER

(Under normal conditions the water-cooled bar lasts about one year unless the water is shut off for several hours. It can be changed in twenty minutes.)

be impossible with a central blast hood for a gas producer of such high capacity. In the Morgan machine the blast is delivered from three hollow radial arms and around the whole circumference of the hollow ring or mantel shown in the illustration. The result is a gentle sustained pressure evenly distributed over the whole surface.

The question of fire-brick lining has also been given unusual attention. To prevent the inner surface of the bricks from fusing with the ash from the coal so that large clinkers would attach themselves to the wall, the thickness of the fire-brick is reduced and it is surrounded with a water-jacket which keeps it cool enough on the inner surface to prevent any slagging action with the ash, but without appreciably reducing the temperature of the burning fuel adjacent to the wall.

As to the composition and the calorific value of the gas produced, the results obtained with one of the first Morgan producer-gas machines by a large steel company are interesting. Twelve-hour samples of the gas were taken day and night for several weeks. They show the great uniformity of the gas. For instance, the CO_2 content in the 11 analyses made during one week, had the values 3.0, 3.2, 2.8, 3.0, 2.5, 2.7, 2.7, 3.0, 2.5, 2.9, 3.0 (average 2.8). The CO content 26.3, 25.4, 28.7, 27.8, 29.2, 26.7, 26.9, 27.5, 27.2, 28.6, 26.7 (average 27.4).

The average values of the analyses for one week were as follows, the corresponding values for the following week being given for comparison in parentheses: CO_2, 2.8 (2.8); C_2H_4, 0.6 (0.6); CO, 27.4 (27.3); H_2, 11.4 (11.1); CH_4 3.6 (3.4); B.T.U. at 32 deg. F., 182.5 (179.0). During part of the time these analyses were made an accurate account of the quantity of coal gasified was kept. The average was 2766 lbs. coal per hour for 120 hours with gas of 178 B.T.U.

At another plant operating open-hearth furnaces eight-hour continuous samples of the gas were analyzed practically every day. The records, covering a period of five months, average 3.5 per cent CO_2, 28.8 CO, and 182 B.T.U. (at 32 deg. F.).

Recently the same plant desired to determine on what gasifying capacity they could safely count as a guide for their future requirements. After increasing the rate to 3260 lbs. coal per hour with every indication that it could be further increased, they decided that they could safely rely on a working capacity of 3000 lbs. per hour, without the quality of the gas suffering at the higher capacity.

The above figures are of significance if compared with best present practice, as a gas averaging 25 per cent CO and a calorific value of 160 B.T.U. per cu. ft. (total at 32 deg. F.) are considered the very best results at present attainable.

Further details of extensive service tests with illustrations of details of design and construction may be found in a new catalog which the Morgan Construction Company of Worcester, Mass., is publishing.

Drop Forged Parts as a Substitute for Brass Castings

The development of a new alloy, placed on the market under the name of "titan bronze," makes it possible to manufacture drop forged bronze parts in place of brass castings. The Titan Metal Company, 1124 Real Estate Trust Building, Philadelphia, control the process of manufacturing the metal, and have granted an exclusive license for the manufacture of finished castings and casting ingots to the Alpha Metals Company, Bellefonte, Pa.

Titan bronze has a high tensile strength, ranging from 75,000 to 85,000 lbs.; an elastic limit of 40,000 to 48,000 lbs.; reduction of area, 45 per cent to 50 per cent, and elongation 22 per cent to 30 per cent, making it possible to use it in many places where steels have been used and where bronze would have been preferable, with the added advantage of its non-corrosive qualities. This point is of particular interest to the chemical and metallurgical industries.

Titan bronze can be worked hot and is valuable for making drop forgings to supersede certain forms of castings and on account of the ease with which it is worked its introduction into practice is expected to have a great effect on hot press work from bars or sheets, hot rolled thread bolts, cap-screws, wood screws, gears, pinions, ship and bolt fittings, and a large number of uses where steel has been utilized with expensive machine operations to produce the finished article.

A valuable application of titan bronze is in form of bronze-covered iron and steel sheets suitable for a wide variety of uses to resist corrosion in various lines of manufacture.

The Preparation of Metal Specimens for Metallographic Tests

To the inexperienced, the tedium of preparing the specimens has often been a barrier to the acquirement of a working knowledge of metallography. Any scientific work may be made difficult and unattractive by the use of crude or cumbersome appliances. While polishing metallographic specimens is a delicate operation, it is not difficult if a few simple precautions are observed. The procedure must, of course, differ somewhat with the character of the metal.

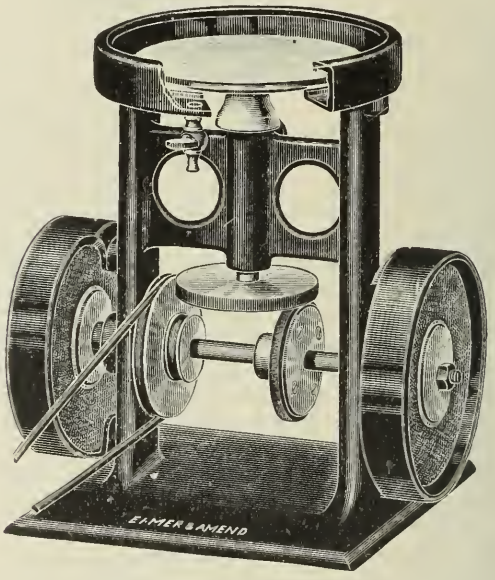


FIG. 1—GRINDING AND POLISHING MACHINE

Messrs. Eimer & Amend, 18th Street and Third Avenue, New York City, have recently placed on the market the Wysor combined grinding and polishing machine which facilitates greatly the preparation of the metal specimens. It is suitable for hard metals and alloys in general, but it is designed especially for the treatment of iron and steel.

It comprises two machines in one, though quite simple in construction. As shown in Fig. 1, a one-piece casting forms the base and frame upon which all the parts are mounted. The grinding wheels are of carborundum, and are carried on the horizontal or driving shaft, the roughing wheel being on one end and the medium and finishing wheels on the other end. The

polishing discs are of brass with cloth coverings, and are easily replaceable on the head of the vertical spindle. This is driven by contact with a friction wheel on the horizontal shaft. It is disengaged when not in use, or when discs are to be exchanged, by means of a cam attached to the frame. The speed at which the polishing discs are revolved may be varied by shifting the friction wheel on the shaft. The disc upon which the specimen is first polished after the grinding is covered with canvas, and the powder used is emery flour. The second disc is covered with broadcloth and tripoli powder is used. The third disc, on which the specimen is finished, is covered with broadcloth, jewelers' rouge being used with this. Separate cases are provided for holding the tripoli and rouge discs when not in use. This insures freedom from grit. Ample protection against flying particles from the wheels is afforded by the cast iron shields.

FIG. 2—BULBS IN TRAY

The polishing powders are mixed with water to the consistency of flowing paste, and may be kept in glass bottles from which they are conveniently poured into the glass bulb holders, which are used for applying them to the discs. When filling or shaking, the small opening of the bulb is closed by pressure of the finger, and when filled the large opening is closed with a tightly fitting rubber stopper. The three bulbs for the pastes and a fourth for clear water are held conveniently on a wooden tray as shown in Fig. 2.

Sprays for Cooling Water

The Spray Engineering Company, 93 Federal Street, Boston, Mass., has placed on the market a new spray nozzle, the design of which is shown in Fig. 1. It is provided with a removable turbine center which has large passageways. The center is held stationary in the nozzle so that there are no moving parts to wear out. The water, in passing through, is given a rapid rotating motion. A central driving jet, which impinges on the rotating water at the orifice, causes the water to be ejected as a fine, dense, uniform spray.

These nozzles are operated at a low pressure. The central driving jet, which is a particular feature of this design, fills in the center of the spray, thus giving it a solid (instead of hollow) conical formation.

One of the principal applications is for **spray cooling ponds,** and for this purpose the arrangement of the sprays is next in importance to the design of the nozzle. As seen in Fig. 2, which shows the spray cooling pond of the Erlanger Cotton Mills, of Lexington, N. C., the nozzles are arranged in groups and are so inclined toward opposing nozzles that when the sprays are operating they are made to collide with each other. By reason of this collision the drops of water are broken into much finer particles than could be effected by the action of the nozzles alone. For it is evident that the finer the spray the greater will be the cooling effect.

Natural ponds without sprays require about fifty times more area than the spray cooling system and in the summer seldom cool the water sufficiently. When water is scarce or insufficient for fire protection a spray pond offers a good source of supply. It is customary to connect the fire pumps direct with the pond.

The cooling of the water is effected in three ways: by evaporation, by radiation, and by convection. That is, heat is abstracted from the water equal to the latent heat of evaporation of the amount of water which evaporates; secondly, heat is radiated from the sprays to the cooler surroundings; and thirdly, heat is carried away by the surrounding air currents by convection.

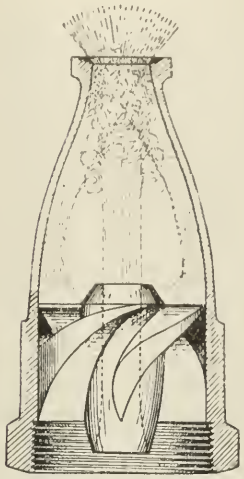


FIG. 1—SPRAY NOZZLE

Those spray cooling ponds are of great usefulness wherever water has to be cooled for condensers, transformers, or water jackets. With the introduction of steam turbines better vacuum and, therefore, colder condensing water have become a necessity. A 26-in. vacuum requires condensing water not over 103 deg. F., a 28-in. vacuum not over 80 deg. F. By the use of the spray system it is possible to obtain an average vacuum of 28 in. the year round in almost all parts of the United States.

A second application of the spray system is for **washing and cooling air,** for instance, for turbo-alternators. The design and construction of the spray turbo air washer are such that every particle of air passing through the machine is forced into intimate contact with fine particles of water from spray nozzles. To insure the complete removal of any dust particles which may have passed through the first set of sprays in the air washer the air is again subjected to the action of cross-scrubbing sprays placed beyond the first set of sprays. The air is next passed through a screen, which removes a large part of the entrained water and prevents any large stratum of air from passing through the washer without coming in contact with wet surfaces. All free moisture in the air is then removed by eliminator plates, the air leaving the washer clean and dry, but with a relative humidity of 100 per cent.

FIG. 2—SPRAY COOLING POND AT ERLANGER COTTON MILLS, LEXINGTON, N. C.

Personal

Mr. **H. G. S. Anderson**, formerly with the Buffalo Company, at Cobalt, and more recently in Mexico, stopped in Denver on his way to Nevada on professional business.

Mr. **Will H. Coghill** has removed to El Paso, where he will continue his work as consulting metallurgical engineer.

Mr. **J. C. Daley**, electrical and designing engineer for the Thordarson Electric Mfg. Company, Chicago, has severed his connections with that company and joined with Mr. J. A. Bennan and Mr. A. R. Johnson in the incorporation of the Jefferson Electric Mfg. Company. The new company is already located and doing business at 847-851 W. Harrison Street, Chicago, manufacturing a complete line of toy, bell ringing, sign lighting and welding transformers, battery switches, steel battery box outfits, make and break and jump spark igniton coils, and a line of high-tension transformers for testing, laboratory and research work.

Mr. **J. V. N. Dorr** spent part of the month of May at the Denver office of the Dorr Cyanide Machinery Co., having previously been farther West on professional business.

Mr. **A. E. Guy**, chief engineer of the pump department of the Providence Engineering Works, lectured in Denver recently on the History and Development of Centrifugal Pumps. Mr. Guy has been in charge of the pumping installation on the Penrose shaft in the downtown district of Leadville.

Mr. **H. W. Hardinge** has left New York for a six weeks' trip to the West and Alaska.

Mr. **James M. Hyde**, of San Francisco, has gone to New York on professional business.

Mr. **Bradley Stoughton**, secretary of the American Institute of Mining Engineers, is visiting western mining centers and has been the guest of honor at luncheons and dinners given by various sections of the Institute.

Mr. **Pope Yeatman** is in Chile inspecting the copper leaching plant at Chuquicamata, which is expected to be put in operation this month. He is expected to return to New York about the end of June.

The following changes in the technical staff of the International Smelting & Refining Co., at Tooele, Utah, were made effective May 1. **A. B. Young**, formerly in charge of the testing plant, is superintendent of blast furnaces. He is succeeded in the testing plant by **B. L. Sackett**, formerly chief chemist. **Carlos Bardwell** is the successor of Mr. Sackett.

Notes

The German Potash Syndicate has authorized the following deliveries of potash for domestic and foreign consumption during 1915 when the embargo is removed. This will enable consumers to know the amount available. Plans for denaturizing potash salts, so that the embargo can be raised, have not as yet materialized.

Kinds of potash	Metric tons of pure potash, K_2O Domestic	Foreign
Carnallite with at least 9 and less than 12 per cent K_2O	4,800	300
Raw salts with 12 to 15 per cent K_2O	266,600	82,200
Fertilizer salts with 20 to 22 per cent K_2O	2,000	33,400
Fertilizer salts with 30 to 32 per cent K_2O	3,600	11,500
Fertilizer salts with 40 to 42 per cent K_2O, including potash fertilizer with 38 per cent K_2O	229,200	68,700
Potassium chloride	54,500	138,300
Potassium sulphate with more than 42 per cent K_2O	1,200	37,600
Potassium-magnesium sulphate	200	14,700
Total	562,100	386,700

New Gas Works.—Under the title "Interesting Installations, Philadelphia," the Improved Equipment Company of New York City has issued a profusely illustrated little pamphlet describing the improvements made by the United Gas Improvement Company at its Point Breeze works in Philadelphia. They included the installation of five benches of mines. These are the Improved Equipment Company's No. 8 benches of mines—21′-0″ thrus—equipped with the Doherty bench fuel economizer and having sectional silica retorts and settings. The illustrations in the pamphlet show the construction in the course of progress.

An electric steel furnace installation of considerable interest is being made in Detroit, Mich., by the John A. Crowley Co. While the details are not as yet given out it will be a six-ton unit of the Grönwall type, which has been used successfully by Sheffield, England, mills for producing high-grade steels and difficult castings. This will be the first installation of this type of electric furnace in this country and it was expected to be put into operation during May. The furnace operates on a two-phase circuit, with two electrodes, each phase being connected to one of the electrodes, the circuit being completed through a neutral pole embedded under the lining of the hearth. This method carries the current through the bath and causes sufficient motion of the molten metal to effect uniform heating and complete distribution of any alloys that may be added, which together with the characteristic non-oxidizing atmosphere insures the production of sound castings of the exact compositions. The design of the Grönwall furnace was described in some detail in an article in our vol. IX, page 573 (November, 1911).

An antimony smelter is in course of erection in the city of San Luis Potosi, Mexico, according to Consul Wilbert L. Bonney. It will be ready for operation when mining and transportation conditions permit ore to be produced and the product shipped. The machinery, which is American, is now ready for installation. It is expected that the plant will employ 150 men and the capacity is to be 3000 tons per annum of refined star antimony. The product will be shipped to the United States. This will be the first and only smelter in Mexico producing refined antimony for the market. It is owned by American capital and will draw ores from its own properties in San Luis Potosi and Queretaro.

The only antimony smelter heretofore operating in Mexico is located at Wadley, a small station on the National Railway, 102 miles north of San Luis Potosi. The Wadley smelter is not equipped for finishing the product, and has exported its product to England for further refining. The Wadley plant was erected about 14 years ago, and has drawn a large part of its ore from the Catorce district.

Chilean nitrate statistics reported by Consul D. J. Myers show a marked decrease in production. In November, 1914, the output was 2,659,875 quintals (of 101.6 lb.) compared with 4,885,869 quintals in November, 1913. Fifty-four plants were working in November, 1914, compared with 127 in the same month of 1913. Government loans to nitrate companies up to November 30, 1914, amounted to 25,836,207 paper pesos (value from 15 to 20 cents per peso). Exports from July 1 to November 30 showed a decrease of 13,000,000 quintals under the corresponding period of 1913.

Tin exports from Bolivia in 1914 were seriously restricted by the war, particularly during the last three months of the year, when the decrease amounted to 36 per cent of the average monthly shipments. The rise in price has partly compensated the loss in tonnage. The shipments for the year are estimated at **34,624 metric tons.**

Tin output of the Federated Malay States in 1914 fell short of that for 1913, being only 109,854,533 lb., a decrease of 2,429,333 lb. The decrease in value was $2,048,620 U. S. gold. The offer of the local government to buy the total tin output at a price of $34.05 per picul (133 1-3 lb.), averted a crisis in the community, as the European war had effectually restricted the market.

Analysis of Brazilian monazite sand by F. H. Lee, of the Geological Service of the Brazilian Government, shows 29.28 per cent P_2O; 31.28 per cent Ce_2O_3; 30.88 per cent La_2O_3 and Di_2O_3; 1.40 per cent SiO_2; 6.49 per cent ThO_2; 0.20 per cent loss on ignition; total 99.53 per cent. The average thorium oxide content of the marketed product ranges from 6.2 to 6.4 per cent. The following table shows the exports of monazite sand from Brazil from 1905 to 1913.

Years and countries	Metric tons	Value
1905	....	$485,184
1906	....	480,843
1908	....	157,475
1909	....	708,092
1910	5437	631,251
To United States	1100	130,650
To Germany	2636	303,953
To France	1691	195,466
1911	3686	539,299
To United States	700	101,352
To Germany	1890	280,996
To France	1096	156,961
1912	3397	527,268
To United States	600	93,197
To Germany	1852	291,467
To France	945	142,604
1913	1437	186,478
To United States	400	51,905
To Germany	256	33,181
To France	778	101,003

The Anaconda Copper Mining Co. expects to have its new copper refinery at Great Falls ready for operation by January, 1916. The capacity will be 10,000,000 pounds of copper per month. The work of construction will be in charge of J. H. Klepinger, superintendent, and Peter Thill, master mechanic. The company recently announced that it would ship copper from Montana via Tacoma, Wash., and the Panama Canal to New York. The routing shows economy over present all-rail shipment to the Atlantic seaboard, and the experiment will be tried to see what the actual result will be.

According to the annual report of the **Portland Gold Mining Co.**, Colorado, for 1914, the net earnings were $590,595. The mine produced 62,997 tons of ore which was shipped to the high-grade mill at Colorado City. The average grade was $23.42 per ton. The low-grade mill at Victor treated 210,132 tons of ore, of which 18,934 tons came from the mine and 191,198 tons from the dump. Dividends paid during the year amounted to $360,000. No statement is made regarding milling costs or recoveries.

The iron industry of Brazil is comprised in one furnace with a capacity of about 15 tons per day, situated at Esperanca. The plant has been operated for about 10 years, and has recently been rebuilt and enlarged.

Branch laboratories of the Bureau of Standards are maintained at Northampton, Pa., and Pittsburgh. The former is devoted to the sampling, testing and certification of cement, and the latter to investigations and tests of structural engineering and miscellaneous materials.

The prospectors' short course offered this spring by the Mackay School of Mines, Reno, Nev., and the Colorado School of Mines, Golden, Colo., was very successful. The attendance at Nevada was 25 and at Colorado 49. The courses evidently meet a need among men engaged in prospecting but who are without much technical education.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Anodes

82,877, October 6, 1868, William H. Remington, of Boston, Massachusetts, assignor to himself, Sarah A. T. Peabody and George D. Allen.

Relates to anodes for electroplating, and describes suspending nickel particles in a platinum basket or woven-wire receptacle; also lining a vat with carbon, connected to the anode, and covering the carbon bottom with nickel particles; also inserting a carbon shelf, or shelf of other suitable conductor not acted on by the solution through a side of the vat and placing the nickel particles on the shelf; also electroplating carbon or other conductor with nickel, and using the composite conductor as an anode. The electrolyte preferred is made as follows: Nitric acid, to which is added about one-twentieth part water, is saturated with nickel, the latter is then precipitated by the addition of carbonate of potash. The precipitate is then washed with pure water and then dissolved in a strong solution of sal-ammoniac, and filtered. It is then ready for use.

129,881, July 30, 1872, George W. Beardslee, of Brooklyn, New York.

Relates to an electrode for electrodepositing metals, and consists of a plate of carbon, platinum, or other conductor that is insoluble in the electrolyte, inclosed in a cover of mosquito-netting or similar very loosely-woven fabric, the fabric holding a layer of granular or fractured metal to be electrolytically dissolved and deposited upon the article to be plated, against each side of the carbon electrode, the whole being supported in a frame of wood or other like material.

155,884, October 13, 1874, Pierre Adolphe Normandeau, of Brooklyn, E. D., New York.

Relates to receptacles for holding granules or fragments of metal to serve as anode, the receptacle being rigid in form and consisting of a flat casing with perforated walls and an open upper end, and preferably made of gutta-percha, or similar material. It is suspended by hooks of insulating material. A conductor of platinum or silver is secured to the inside of the receptacle and contacts with the metal to be dissolved.

166,367, August 3, 1875, August Hermann and Warren H. Taylor, of Stamford, Connecticut.

Relates to anodes for electroplating, and consists preferably of a carbon plate having imbedded in its surface, while the carbon mass is still plastic, a number of nickel granules, or fragments of nickel anodes. If a platinum plate is used the granules are secured to the platinum by shellac, glue, or other suitable adhesive substance. See the reissue of this patent, No. 7,489, dated February 6, 1877.

166,433, August 3, 1875, Edward Weston, of New York, N. Y., assignor to Stevens, Roberts and Havell, of Newark, New Jersey.

Relates to an anode in which particles of metal or an oxid, carbonate, or other compound thereof, or metallic dust, is mixed with a cement such as powdered carbon and molasses, or some other substance capable of forming a coherent paste. The mass thus obtained is placed in molds and subjected to pressure, dried, and then baked out of contact with air until the mass is thoroughly carbonized, and a solid, compact, coherent mass is obtained. When nearly exhausted of metal by use, the residue may be ground up and mixed with a fresh mass for a new anode.

Reissue 7,489, February 6, 1877 (original 166,367), August Hermann and Warren H. Taylor, of Stamford, Connecticut, assignors, by mesne assignments, to the Yale Lock Manufacturing Company, of same place.

Relates to anodes for electroplating, and consists preferably of a carbon plate having imbedded in its surface, while the carbon mass is still plastic, a number of nickel granules or fragments of nickel anodes. If a platinum plate is used the granules are secured to the platinum by shellac, glue, or other suitable adhesive substance.

208,003, September 10, 1878, Adolph C. Wenzel, of Brooklyn, New York.

Relates to a receptacle for holding grain nickel or other metal for use as an anode in electroplating. The receptacle consists of two carbon or graphite plates, perforated with many fine holes, and separated by a U-shaped carbon or graphite separator, the plates and separator being united by hard-rubber bolts. The receptacle is supported by a clamp carrying a hook by which it is suspended from a conductor above the plating tank. The grain nickel is placed in the receptacle, and makes contact through the carbon sides thereof.

223,265, January 6, 1880, Joseph Wharton, of Philadelphia, Pennsylvania.

Relates to nickel anodes for electroplating and consists of a wrought, rolled, or hammered cast plate of nickel, the physical condition of the malleable metal effecting a greater economy in use than that obtained with the granulated metal.

226,576, April 13, 1880, Abraham Van Winkle, of Newark, New Jersey.

Relates to anodes for electroplating and consists in a frame surrounding the side and bottom edges of a rolled or plate anode, for the purpose of preventing pieces that may be dissolved loose from falling to the bottom of the tank.

Book Reviews

Industrial Chemistry. By **Rogers** and **Aubert.** Second Edition. Edited by Allen Rogers in collaboration with many specialists. 1005 pages, 305 illustrations. Price $5.00 net. New York: D. Van Nostrand Company.

The publication of this second thoroughly revised and enlarged edition is timely. No such opportunity as that presented to-day has come before the chemists of this country for a fuller development of our natural resources. The work deals with American practice, and from the fact that the present edition has the imprint "fifth thousand" we learn that it has been appreciated.

The range of subjects is wide. The topics are treated of by men having experience in more fields than those they write of, and so a broader view of each subject is given. Ten new chapters have been added, recognizing the newest features in chemical progress. One cannot but be impressed with the constructive work now being done by the professional chemists in comparison with the older type of analysts. As the work widens better conditions will obtain and young men will be attracted to chemistry as a life work. This volume will undoubtedly be the means, in many instances, of creating interest among students and manufacturers in chemical problems. Heretofore their interest has been largely in mechanical devices and methods. Abundant references to special treatises are given at the end of each chapter. Particular pains have been taken to make the principles involved in each manufacture clear. Often several different methods of carrying out a chemical reaction are given. There are diagrams illustrating the flow of material from the raw state to the various finished products, and schematic plans of apparatus give clear conceptions of what the several processes are intended to accomplish. There are also abundant illustrations of plants and of apparatus.

The practical part of the book is excellent and most creditable to the publishers.

* * *

The Cyanide Handbook. By **J. F. Clennell.** Second edition, octavo, 602 pages, illustrated; price $5.00. New York: McGraw-Hill Book Company.

This is a *vade mecum* for assayers, chemists, foremen and managers of cyanide plants, giving all the details of chemical and physical principles and practice utilized in the operation of such plants. It is an eminently practical book, written in the true scientific spirit by a scientifically practical man.

* * *

How to Build Up Furnace Efficiency. A handbook of fuel economy. By **Jos. W. Hays.** 126 pages, illustrated. Seventh edition. Price $1. Chicago: Jos. W. Hays.

This a popularly written little treatise discussing in five chapters why fuel is wasted, how it is wasted, how to "spot" fuel waste, how to stop it, and how to keep the waste stopped.

The book is intentionally written in a popular style and anecdotes are liberally used for purposes of illustration, for the author's thesis is that the men to stop the fuel waste are the men who are doing the wasting —the practical firemen. Their interest must be aroused and kept. The author emphasizes that just as all practical men know how to use thermometers and scales, so they can be shown how to use draft gages and gas analyzers, even if they don't understand the theory.

The book is well written for the purpose for which it is intended and should do much good.

* * *

Analysis of Alloy Steels. Methods of the Chemists' Committee of the United States Steel Corporation. 70 pages. Price $1. Copyrighted by **J. M. Camp,** Carnegie Steel Company, Pittsburgh, Pa.

This pamphlet prepared under the direction of the Chemists' Committee of the United States Steel Corporation (J. M. Camp, chairman) on the Sampling and Analysis of Alloy Steels, is now being distributed to its various chemical laboratories. This makes the fifth pamphlet so distributed, whose purpose is to unify and simplify methods of analysis. The other four pamphlets, with their date of issue, cover the Sampling and Analysis of Cases, 1911: Pig Iron, 1912: Ores, 1914 (second edition) and Plain Steel, 1914. To curtail the numerous requests for these pamphlets a charge is now made of $1 each to persons and firms outside the corporation.

The pamphlet covers both sampling and analysis of alloy steels. Methods for the determination of carbon, manganese, phosphorus, sulphur, silicon, tungsten, cromium, vanadium, nickel, cobalt, copper, molybdenum, aluminium and titanium are given.

* * *

Joplin News Herald's 1915 Zinc and Lead Handbook. By **L. L. Wittich.** 60 pages. Price 25 cents. Joplin, Mo.: Joplin News Herald.

This is the first edition of a little statistical handbook which is intended to be published annually. To those interested in zinc and lead statistics it should prove interesting and useful. Besides data on zinc and lead production in the world and in the United States, on imports and exports, on consumption, on weekly prices of zinc and lead ores during 1914, etc., it contains very full information on the activity of the Missouri-Kansas-Oklahoma district.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, JULY, 1915 No. 7

Published Monthly by the
McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.
A. E. Clifford, Secretary. John T. DeMott, Treasurer.

239 West 39th Street, New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.
Rocky Mountain Office.....421 Boston Bldg., Denver, Colo.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for July, 1915

EDITORIAL:
Patent Suit Procedure 405
Steel Shape and Rod Production 405
Effect of Zinc Prices on Cyanidation 406
The Field for Engineers 406
Steel Corporation Allowed to Live 407
READERS' VIEWS AND COMMENTS:
The Neutrality of Science. By Joseph W. Richards 408
Flotation Results. By Rudolf Gahl 408
An Interesting Application of Colloidal Chemistry. By Daniel T. Pierce 408
Flotation Suit 409
Bakelite Suit Decision 411
Court of Appeals Decision in Nickel-Chromium Resistor Suit. 414
The Western Metallurgical Field 415
The Iron and Steel Market 417
The Western Trip and the Los Angeles and San Francisco Meetings of the American Institute of Chemical Engineers.. 418
The Western Trip of the American Chemical Society 419
Special Trains of Civil, Mining, Mechanical and Electrical Engineers to International Engineering Congress 419
The Western Trip of the American Electrochemical Society.. 419
The Corrosion Problem Before the American Iron and Steel Institute 420
Cyanidation of Low-Grade Sulphide Ores in Colorado—I. By H. C. Parmelee 421
Furnace Curves. By R. J. Weitlaner 425
Blast-Furnace Plant Auxiliaries and General Arrangement. By J. E. Johnson, Jr. 429
The Relative Migration Velocity of the Ions in Complex Electrolytes. By A. Mutscheller 439
Good Advice to Consulting Metallurgists 442
Metallurgical and Chemical Engineering in Great Britain 443
Synopsis of Recent Chemical and Metallurgical Literature 446
Recent Chemical and Metallurgical Patents 449
Welding Up Scrap Nickel Anodes 453
The Course in High Temperature Measurements at Purdue University 454
A New Diaphragm Pump 455
British Producer Gas and Ammonia Recovery Plant 456
Exhibits at the San Francisco Exposition 458
Air Compressor 460
American-Made Porcelain Ware for Chemical Laboratories.. 461
The Non-Ferrous Metal Market 461
Personal 461
Obituary 462
Newspaper Chemistry 463
National Exposition of Chemical Industries 463
Digest of Electrochemical U. S. Patents 463
Book Reviews 464

Patent Suit Procedure

This issue contains an unusual amount of news on important patent suits: a sketch of the present status of the flotation suit, an account of the District Court decision in the bakelite suit, and an account of the Court of Appeals decision in the nickel-chromium resistor suit. The flotation suit is probably the most momentous patent suit now awaiting decision, as flotation will ultimately become one of the greatest agents in the conservation of our mineral resources—but not until the patent situation is settled. To accelerate the slow pace of patent law procedure is one of the greatest industrial problems of the day.

In this respect the bakelite suit is of interest, as it was one of the very first suits tried under the new open-court system. The final argument was made on Feb. 20 and 21, 1914. The decision was rendered on June 12, 1915. While the interval seems long, it is safe to assume that under the old rules the trial would still be going on for years to come.

Nevertheless our methods of court procedure could be made considerably less complicated. Reforms could be introduced whereby the presiding judge would not be compelled to study in every case every detail of highly specialized scientific or technical testimony, which requires not only intelligence, but long technical training. Matters would be still further simplified if the question of validity or non-validity of a patent could be referred to a technical court, where simple, relatively inexpensive, and direct proceedings could be instituted, similar to the nullification proceedings in Germany. The decision of such a technical court would be a direct guide for the judge so as to decide on the question of infringement. Some reform along such lines would be eminently desirable.

Steel Shape and Rod Production

Statistics of production of shapes, rods and nails in the United States in 1914 have just been presented by the Bureau of Statistics of the American Iron and Steel Association.

Measured by the basic material, pig iron, 1914 was a decidedly poor year, for the pig iron production, 23,332,-244 gross tons, was almost 25 per cent less than the record output made in the preceding year. The production of structural shapes suffered slightly more than the average, as the 1914 production, 2,031,124 gross tons, showed a decrease of 32 per cent from 1913. That was quite natural, for as the total demand for iron and steel rises and falls from year to year, the fluctuations are made more largely by the materials which enter into more or less permanent structures, or are involved in

the investment of capital, while the articles of everyday consumption show much smaller fluctuations. The production of structural shapes has shown more conspicuous illustrations of this fact than the illustration afforded by the 1914 statistics, for in 1908 the production of shapes was less than half the production in 1906, whereas the production of pig iron suffered a decrease of only a trifle more than one-third.

For an article representing common everyday consumption, no better commodity could be selected than wire rods, and it is a happy chance that brought the rod statistics for 1914 to light at the same time as the shape statistics. We find that the production of rods in 1914, 2,431,714 gross tons, was only 33,000 tons less than the production in 1913, and we also find, interestingly enough, that 1913 was not the banner year for rods, 1912 retaining that honor with 2,653,553 tons. There have indeed, been nothing like violent fluctuations in the production of rods since the early days of the industry, when the production was increasing rapidly because the wire nail was supplanting the cut nail. The production of nails, cut and wire, has been quite steady; of the past 11 years the best was 1912, with 15,638,115 kegs, and the poorest year 1908, with 11,619,154 kegs. No other important steel commodity has shown such slight variation.

A rather interesting statistical event occurred in 1914, the production of rods for the first time exceeding the production of rails. This was an event long predicted. In fact, it was predicted altogether too soon, at a time when the production of rods was experiencing a temporarily rapid growth on account of the supplanting of the wire nail by the cut nail, already referred to. There is not the least reason to suppose that rods have permanently passed rails in tonnage. The passing in 1914 was due simply to the fact that in an "off" year rail production suffered severely while rod production suffered scarcely at all. In 1914 the rod production was 2,431,714 tons and the rail production 1,945,095 tons, but in 1906, eight years earlier, the rail production was 3,977,887 tons, and it will probably be easier, in future years, for the rail tonnage to regain that height than for the rod production to attain it. Given still more time, however, the rod tonnage may permanently pass the rail tonnage.

Effect of Zinc Prices on Cyanidation

With spelter at 25 cents per pound, zinc sheets at 30, and zinc dust at 28 to 32, a decided dislocation has resulted in the cost of precipitating cyanide solutions. The sudden prosperity of the producer of zinc is reacting unfavorably on the producer of gold and silver by the cyanide process, raising the cost of precipitation to a point where substitute methods are being considered. In spite of technical improvements in precipitating practice, the irreducible minimum cost has assumed abnormal proportions. Six months ago spelter was quoted at 5.5 to 6 cents per pound, zinc sheets at 8.5 to 9, and zinc dust at 10. Current prices are three to five times as great.

In the reports of those companies that give annually a detailed cost of milling operations, we find the following data on precipitation: At Goldfield Consolidated, using zinc dust, the cost of precipitation in 1914 was 6.2 cents per ton of ore milled, out of a total milling cost of $1.606. At the Hollinger, where zinc dust also is used, the precipitation cost of 6.3 cents per ton of ore milled, out of a total cost of $1.237. For similar precipitation at the Commonwealth, in Arizona, the cost was 11.6 cents, out of a total of $1.879. These precipitation costs range from 3.86 per cent to 6.17 per cent of the total cost of milling, ranking with the costs of crushing and conveying, settling, filtering and concentration, where the last is practised. Excepting stamping, tube-milling, and agitation, which show the highest itemized costs, precipitation is quite as important an item as any other in the total cost of cyaniding.

It is not surprising, therefore, that managers are giving careful thought to the present conditions. Precipitation by aluminium dust for Western cyanide mills has long since been investigated by some companies, but as far as we are aware none has adopted it. Other changes have been contemplated in general methods of operation. In one instance, where cyanidation had superseded amalgamation and concentration, the advisability of temporarily reverting the former practice was investigated, but found unprofitable even at the present high cost of zinc for precipitation. While this is a strong endorsement for cyanidation, the company's action shows the influence of current conditions.

One of the most striking effects of the high price of zinc is a renewed interest in electrolytic precipitation of cyanide solutions. Experiments of this sort are under way at one mill, and the early results appear encouraging. The work is in competent hands and the outcome will be awaited with interest. Regardless of the ultimate effects of the present zinc market on cyanide metallurgy, all the investigations under way indicate a healthy condition in the management of our metallurgical concerns.

The Field for Engineers

With the recurrence of the annual graduating season, new accessions have been made to the ranks of the engineering professions, and one hears again the old familiar question, "What becomes of all the engineers?" The same query may well be put regarding lawyers, physicians and others who have pursued a course of special training. The inference is that all of these specialists cannot find lucrative employment in their chosen lines; that the professions are overcrowded and opportunity for success is consequently limited.

It is a fact that there is a growing tendency for engineering graduates to assume vocations apparently unrelated to the particular branch of engineering in which they were graduated. This, however, is not an argument against the pursuit of an engineering education, for the fundamental qualities of such training are adaptable to success in a wide variety of commercial operations. The engineering graduate, of whatever brand, should be well fitted to observe keenly, analyze with precision, draw correct conclusions, discriminate

between essentials and non-essentials, and attain his ends by the most direct and economic route. Such qualities as these are appropriate in the administration of any branch of business, and should enable their possessor to rise rapidly and prove himself invaluable. It makes little difference what particular label is placed on the engineering graduate. If he is well grounded in the fundamental qualities of an engineer, he is fitted to become a most useful member of society.

There is ample evidence that the ramifications of engineering are extending into many branches of business. National, state and municipal affairs require engineering direction. Imagine the beneficent results flowing from a legislature composed of fewer lawyers and more engineers; not that lawyers are unnecessary, but that they deal unintelligently with matters foreign to their knowledge. Salesmanship of the highest type is open to engineers in fields where the "drummer" is inefficient. The field of insurance also is open, with the adoption of workmen's compensation laws in the mining states. Recently we were asked to recommend to an insurance compay an engineer capable of inspecting mining and milling properties for purposes of setting the premium rates for liability insurance. Such an engineer might never mine or mill a pound of ore, but he could develop a field for special talents. The uses of an engineering training are not confined to actual field work. Society has many benefits to gain from a wider spread of such training among young men.

Steel Corporation Allowed to Live

Practically everybody but the plaintiff appears to have been pleased by the decision handed down June 3 in the United States Steel Corporation dissolution suit in the United States District Court of New Jersey. As a matter of fact, it would not be necessary to await expressions of opinion after the decision, for the witnesses the corporation brought to the hearings represented the majority of its competitors and customers, and there was favorable testimony also as to the corporation's treatment of its employees. Naturally the interests thus arrayed on the corporation's side are pleased with the verdict.

Comment that has been passed upon the case since the decision was rendered has run so largely to the expression of gratification upon the result that some interesting long-range observations have not been emphasized as they should be, if we as thinking individuals are to profit by the experience. How strange it would seem to the conventional inhabitant of Mars if he were given but the skeleton, that the Sherman law was passed in 1890, that combinations in restraint of trade were formed in 1898, 1899 and 1900, that these combinations were themselves united in 1901, that they entered into illegal arrangements with outside interests at various times as late as 1908, that in 1911 the government brought suit under the Sherman law and that in 1915 the corporation was given a clean bill of health as a result of that prosecution! The Martian would probably at once inquire why the suit was not brought earlier, when a conviction, apparently, could easily have been secured, and if nobody desired a convinction at that time, why the law had ever been enacted.

Reply might be made that the Knight Sugar Trust decision of 1904 had apparently interpreted the law so that it could not be made to apply to the Steel Corporation or the prior consolidations, while subsequent decisions suggested that possibly the Steel Corporation might be found guilty, thus encouraging the Government eventually to bring the suit. At the time of the Knight decision, however, the Sherman law was already fourteen years old, and it was only seven years older when the steel suit was brought.

One can scarcely avoid the conclusion that public thought has had much to do with molding the course of events. The Sherman law was not taken very seriously in its early years. It put some inconvenient restraints of secrecy upon those who entered into trade restraint combinations, but enough was known to have formed the basis for many prosecutions if the people had been ready for them. Later there was a great awakening on the part of the people as to their commercial rights, but at first their desires were inadequately expressed for they had not the knowledge and experience. The revolution in public thought was one thing and the clamor of the "muckrakers," as we now know, was another. While condemning the muckrakers, the leaders in industry and finance recognized the rightness of the revolution in public thought, and reforms were instituted. Judge Gary, himself, the chairman of the Steel Corporation, has frequently and strongly expressed the view that business needed to be reformed and that it had reformed. The decision in the steel suit, including both the opinion rendered by Judge Buffington and the separate opinion by Judge Woolley, reaching the same conclusion but by a separate process of reasoning, condemns much in the Steel Corporation that has passed into history, while entirely vindicating the corporation as it stands to-day, or as it stood on the day upon which the suit was brought.

Thus we have a gradual changing and molding of public opinion whereby the rights of the public are declared, and a changing in the conduct of business whereby those rights are recognized.

What is particularly gratifying is that sufficient time chanced to be allowed for "big business" to be judged by its performance and not by academic theory. It was an economical necessity that "big business" should come. Given time it would show its right to exist by benefiting the public. Fortunately that time was furnished. Instead of regarding the corporation as a menace because it was big, the court observes in substance that the bigness was desirable for economic reasons, and gives the readily comprehended dictum that it is not the size of the corporation, but the importance of the power that was not acquired, that should govern the decision in the case. The extent of the power that was not acquired was shown clearly by the testimony, that nine important competitors of the corporation had grown in capacity at much greater percentage rates than had the corporation, and that the corporation's proportion of the country's total output had steadily diminished.

Readers' Views and Comments

The Neutrality of Science

To the Editor of Metallurgical & Chemical Engineering

SIR:—Many, many lamentable things have happened in the "World War" which is desolating Europe, but one of the most unexpected, to scientific men, has been the regrettable action taken by the British Iron and Steel Institute, in London, on May 14th last. At the meeting on that date the Council of the Institute put the following resolution before the members present, which was "carried unanimously":

"That the names of all alien enemies be struck off the list of members of the institute, and that steps be taken to amend the by-laws so that they provide for the future that, in the event of war existing between this and other countries, citizens or subjects of which are honorary members or members of this Institute, such honorary members or members shall *ipso facto* cease their membership."

Being a born Englishman, the undersigned may not lightly be charged with anti-British sympathies; being also a member of the Iron and Steel Institute, he may be granted the right to express publicly his disapproval of the above action. But speaking from the broader standpoint of a believer in the international character of science and the salutary saneness of the scientific spirit, he wishes to voice his deep regret that such a dignified Institute, such an honored and honorable society, should stain its annals by an act of such lamentable folly.

In this pandemonium of strife, collapsing of the safeguards of civilization, reversion towards primitive barbarism, where shall the seeds of future peace and harmony be found if the fraternity of scientific brotherhood and mutuality is also swept into the abyss? There must and there will come an "after the war," when reconstruction of the desolated earth will be the common task. Then conquerors and conquered must and will work towards a common end, and then will come the need of mutual co-operation and re-established goodwill. And where could a better starting point be found than in the fraternal bonds of international scientific co-operation?

Alas, our ideals are being shattered and our hopes falter when we contemplate the short-sighted action of the venerable Iron and Steel Institute. All honor to Professor Turner, who raised a protesting voice in the discussion, telling them that they would live to sorely regret their hasty action.

The writer believes that he voices the sentiments of the majority of members of the Iron and Steel Institute in America, in deploring this ill-advised, short-sighted, and altogether regrettable action. He believes, further, that this would be the nearly unanimous view of American scientists in general. The escutcheon has been blotched. Members of the Iron and Steel Institute in Great Britain repent your haste, rescind the action, and wipe out the blot.

Lehigh University.
June 15, 1915.

JOSEPH W. RICHARDS.

Flotation Results

To the Editor of Metallurgical & Chemical Engineering

SIR:—May I call your attention to an error in the editorial on "flotation as a conservation measure" in your June issue?

You say that the recovery from sulphide ore in the Inspiration Company's experimental mill last February was 90.3 per cent, or from 20 per cent to 25 per cent greater than at five other porphyry copper mines. This is evidently a misunderstanding of a statement in Mr. Mills' yearly report, which was to the effect that 90.3 per cent of the copper occurring in sulphide form was being recovered. It is known, of course, that all these porphyry ores are partly oxidized and that to get a fair comparison between the work done at different reduction plants it is necessary to discriminate between recovery made on the sulphide copper contents and on the oxide copper contents, as Mr. Mills has done in the report in question.

I think it will be found that the other porphyry copper mines also make a fairly good sulphide recovery, although there is no doubt that the flotation process will assist materially in raising it. But improvements of from 20 to 25 per cent with which you credit us are out of the question, as long as the oxide recovery is not raised materially. The prospects are bright that this will be done in the near future.

Inspiration Consolidated Copper Co.,
Miami, Arizona.

RUDOLF GAHL.

An Interesting Application of Colloidal Chemistry

To the Editor of Metallurgical & Chemical Engineering

SIR:—It is fairly evident from the progress already made that colloidal chemistry will within a short time place many industries under heavy obligations to this rapidly advancing branch of science. Some suggestion as to this is contained in the chapters on the applications of colloidal chemistry in tanning, dyeing, soil improvement, sewage purification and biology in a volume on this subject by W. W. Taylor of the University of Edinburgh ("Chemistry of Colloids and Some Technical Applications"; Longmans, Green & Co., New York, 1915). A striking example of the aid this department of chemistry may afford in explaining hitherto unaccounted for industrial results, and in providing a line along which rational improvement may be sought, is found in the investigations of Clifford Richardson in connection with the collodial nature of Trinidad asphalt and the results of these investigations as applied to the asphalt paving industry.

Mr. Richardson's work in this connection is also a good example of the value of the chemist's services. A lecture on colloids delivered by Wolfgang Ostwald, the great authority on this subject, at the laboratory of the College of the City of New York, early in 1914, supplied the first suggestion that colloidal chemistry could aid the asphalt industry, although Dr. Ostwald made no special reference to bitumens in his review of the past ten years' study of colloids. In a memorandum dictated the day after the lecture, however, Mr. Richardson said: "It is evident that a portion of the clay in Trinidad asphalt is in this condition, and this throws a great light on the character of this substance and explains why it differs in some respects from all other bitumens with which we are acquainted. It has very probably acted as a catalyzer in producing a peculiar form of bitumen, and by its presence in the bitumen, as used, confers upon it properties which are unique. The field this affords for investigation is interesting and worthy of study."

Since the date of this memorandum Mr. Richardson has spent a year of study and laboratory investigation with results that should mean more to the asphalt paving industry than any discovery that has been made

in many years. The conclusions from this study clear up many conceptions that have heretofore been held merely as theories, or which have been applied in a rather haphazard manner; they point the way toward rational rather than empirical methods in the preparation of paving formulas.

Every since Mr. Richardson's standard work, "The Modern Asphalt Pavement," appeared in 1905, the fact has been generally realized that the perfection of a sheet asphalt paving mixture will depend very largely on the surface area of the particles composing the mineral aggregate of sand or filler entering into the mixture. In the minds of most of those—even the experts—who are engaged in the industry, the grading and the fineness of the mineral aggregate is supposed to have little importance outside of the extent to which a fine grading will "carry" the bitumen. Any paving man knows that a fine aggregate will carry more bitumen than a coarse aggregate, but that is about as far as he has gone.

Mr. Richardson's investigations have now shown that the extent of surface area presented in any mineral aggregate, especially if it embodies colloidal material, has a great importance in addition to the carrying of the bitumen.

A pound of coarse sand such as might be used in a paving mixture is found to contain 129,030,065 particles with 44,378 square feet of surface. A finer sand of the type used in some of the most successful pavements laid in New York in the 90's contains 232,075,324 particles to the pound, these particles having 60,503 square feet of surface. Going a step further in these investigations it is found that the number of square feet of surface in a pound of dust or filler used in a paving mixture is 527,821. Dust or filler of the latter characteristics, that is, of from 0.08 to 0.0025 mm., is estimated to run 192,715,000,000 particles to the pound, and has been considered the ultimate of fineness in paving mixtures.

These figures are given for the purpose of permitting a comparison between ordinary conceptions as to how fine the aggregate of a paving mixture may be and the degrees of fineness we encounter in the field of colloids. For the purpose of comparison with the above it is pointed out by Mr. Richardson that if the amount of material represented by a cube having a dimension of 1 cm. is reduced to the coarsest colloidal size (ten-thousandths of a millimeter in diameter) the surface area of the material in the 1 cm. cube would be increased 100,000 times.

It had already been demonstrated that a large surface area was a necessary feature of the mineral aggregate of an ideal paving mixture; hence the addition of the finest dust that could be obtained. Service tests had shown that pavements such as those laid on Fifth Avenue, New York, the Victoria Embankment in London, and Vermont Avenue, Washington, D. C.—the latter being in use for 35 years—containing the largest amount of the finest obtainable material, are the most durable. The reasons for this, however, were not entirely clear, except in the particular already pointed out; namely, that the finer the aggregate the more bitumen it would carry without excess.

All of these pavements were constructed with asphalt containing colloidal clay, and it is now appreciated as a result of Mr. Richardson's studies, why the results in the cases cited were obtained. The power of selective adsorption possessed by colloids is shown to be of prime importance in the sheet asphalt paving industry, because the surface of the mineral aggregate adsorbs selectively and holds with great power the bitumen which is used as the binding material or cement. In Trinidad asphalt there is a considerable amount of mineral matter present in a dispersed solid colloid form which shows great capacity for adsorption, selecting the denser portions of the bitumen and forming a combination which gives great body and density to this binding material.

The bitumen under these conditions has a further influence, in that it serves as a protective film to the highly dispersed particles. Various bitumens differ in the degree in which they exercise protective properties, this difference being apparently in proportion to their viscosity or density; and there is a close relation between this property and the success achieved with them in the making of a sheet asphalt paving mixture. The more viscous the bitumen and the larger the amount of colloid material it contains, the thicker will be the film which adheres to or is adsorbed by the mineral aggregate, and, consequently, the greater cementing power of the bitumen which forms the thicker film.*

Barber Asphalt Paving Co.,
Philadelphia, Pa.

DANIEL T. PIERCE.

Flotation Suit

On May 27, 1915, the hearings in the case of Minerals Separation, Ltd., vs. Miami Copper Company were concluded after a nine weeks' contest in the United States Court for the District of Delaware at Wilmington, presided over by the Hon. Judge Bradford. In view of the enormous industrial importance of this case, the following summary of the present status should be of very considerable interest:

When suit was first brought by Minerals Separation, the Miami Copper Company was merely technically liable to an infringement suit, owing to its use in an experimental plant, of a 60-ton Minerals Separation type of flotation machine. This first proceeding, in form of two separate suits, was based upon two of Minerals Separation patents—patent 835,120, for the use of "less than one per cent of oil," and patent 962,678, covering the use of soluble frothing agents.

About the first of August, 1914, the Miami company commenced experimenting upon a 300-ton plant with what is generally known as the Callow type of cell—a flotation device in which air bubbles are *not* introduced by agitation, as was done by mechanical beaters in the Minerals Separation machine, upon the use of which the original suit was brought.

The first suits were then withdrawn and a new suit in equity was instituted, alleging infringement of three of the Minerals Separation patents, the two above mentioned and a new one which had just been issued, 1,099,699. The claims of the latter cover the use specifically of aromatic hydroxyl compounds as frothing agents *in the cold* and *without acid*. The bill of complaint urged that the Miami Copper Company had infringed in the use of these three patents conjointly.

Interrogatories were filed by the complainant and were most frankly answered by the defendant.

It will be seen that the Miami suit introduces several features which were not present in the Hyde case.† This case was decided in favor of Minerals Separation in the lower court of Butte, but the decision was reversed in the Superior Court of San Francisco, and the case is now awaiting a hearing in the United States Supreme

*Those who are interested in pursuing further the result of Mr. Richardson's investigations may be referred to the following articles: "A Unique Geophysical Phenomenon," *Journal of Physical Chemistry*, Vol. 19, No. 3. "Colloids in Their Relation to Bituminous Road Construction, the Asphalt Paving and Other Industries," *Technology Monthly* and *Harvard Engineering Journal*, Vol. II, No. 2. "The Theory of a Perfect Sheet Asphalt Surface," *Journal of Eng. and Ind. Chemistry*, June, 1915

†See METALLURGICAL & CHEMICAL ENGINEERING, Vol. XII, p. 362 (June, 1914).

Court. In the Hyde case only patent 835,120 was at issue, and since the operations in that case had been carried on in a machine, employing agitation with mechanical beaters, the defense had largely to depend upon breaking down the validity of the patent for less than 1 per cent of oil (patent 835,120). The Superior Court in San Francisco decided that this patent was invalid in that the reduction of oil to a point less than 1 per cent had shown nothing new besides an economy in oil. In the Miami case it became, therefore, now incumbent upon the complainant to demonstrate to the court that some new effect, some new result other than mere economy, is produced when the oil is reduced to this extremely minute quantity, while the defendants had to show that in the use of less than 1 per cent of oil no effect that was not also attained by the prior-art processes, except mere economy, is produced in the operation of patent 835,120.

The pneumatic cells of the Miami process having no mechanical beaters or agitators, but having the finely divided air admitted through a porous bottom from blowers or fans, left open more of a question as to infringement, since the defendant company maintained that its mode of operation did not infringe any of the claims of the patents in suit. Upon the other hand, the witnesses of Minerals Separation, who had visited the Miami plant, testified that all of the agitation necessary to produce their agitation froth was found in certain centrifugal pumps, Pachuca tanks, etc., which formed adjuncts to the pneumatic cells, and that the cells themselves were in fact agitators.

The defendants, on the other hand, maintained that if some agitation froth were produced through the agency of such accessory apparatus it was negligible in quantity and was not utilized in the subsequent separation in the cells. To sustain this claim they introduced figures and assays in evidence tending to show that in the present operating plant the results were identically the same, when two sections of the mill were operated side by side, one section having the Pachuca in operation and the other section having the oil merely fed into the launders in which the feed to the flotation plant was flowing with no mechanical handling other than a bucket elevator.

In the demonstrations to establish the non-validity of the less than 1 per cent of oil patent the defendants exhibited to the court models of various prior-art machines, such as those of Carrie Everson, Froment, Kirby, etc., in which experiments were made in court, and concentrates produced with quantities of oil varying from ½ per cent up to 25 per cent of oil. On the other hand, the experts of Minerals Separation contended that the defendants' apparatus has no foundation whatever in the prior art, and that all such results were obtained by defendants through their availing themselves of present-day knowledge, and not of the engineering knowledge at the time of the patents or processes in question, and the complainants (Minerals Separation) exhibited their conception of the prior art, endeavoring to illustrate to the court how utterly these prior-art processes had failed to produce any commercial results except upon a laboratory scale. They maintained that not one of these so-called prior-art processes had actually been in successful commercial operation.

The display of models in the court room at the close of court was most interesting, when all these exhibits were seen together as the various deposits of complainant and defendant. Possibly the most interesting of the prior-art disclosures was the description of froth-producing experiments as described by three students of the University of California in *California Journal of Technology* of November, 1903, in which they clearly set forth the distinction between the "lake effect" of the bulk oil (Elmore) process and the "foam effect" due to the "beating in" of air as in the Minerals Separation practice, describing the demonstration corresponding to the "bottle test" used as a field test as to the suitability of ores for treatment by the Minerals Separation engineers.

Possibly the most novel feature of the demonstrations was the use of a moving-picture film to illustrate certain laboratory experiments which had been made at a laboratory in New York. This, among other things, was to illustrate the action of air bubbles in their attraction for oiled and non-oiled mineral particles, and essentially to show that when particles were oiled with less than the Cattermole proportion, that is with less oil than is necessary to make them adhere, their affinity or attraction for the froth-producing air bubbles became effective, whereas it was stated to be a general law that particles oiled with sufficient oil to cause them to adhere had little or no attraction for air bubbles. The Miami experts showed by a similar set of experiments that the broad statements of the picture film were not sustained, and that there did not exist any actual difference in behavior of oiled and non-oiled particles as supposed by the Minerals Separation.

This discussion of the film constituted an important feature of the proceedings of the trial. The ingenious manner of observing and illustrating the action of air bubbles in a moving picture was devised by Dr. Wm. M. Grosvenor of New York.

The experimental demonstrations before the court were mostly in connection with patent 835,120, which covers the use of less than 1 per cent of frothing agent.

With reference to patent 926,678 the defense in argument contended that soluble frothing agents had been disclosed in previous patents, and with respect to patent 1,099,699 (covering flotation without acid and without heat) that the use of both acid and heat had been disclosed as optional in various prior patents, though the use of both acid and heat had become general in the application of flotation.

Mr. Henry D. Williams of New York, who had handled the case of Minerals Separation, made the principal argument for the plaintiff. He was followed by Mr. William Houston Kenyon, also of New York, in an able review of the case, with the legal citations.

Mr. Walter A. Scott of Chicago, who had the case for the Miami company, made the principal argument for the defense. He was followed by his law partner, Mr. Thomas F. Sheridan, who took up the legal citations. Mr. Scott had also handled the defense in the Hyde case, above referred to. He showed his wonderful grasp of the subject matter by the readiness with which he referred to the records of the previous, as well as the present case, in replying to Judge Bradford's numerous questions.

Dr. Adolph Liebman of London was chief expert for Minerals Separation, and Dr. Samuel P. Sadtler of Philadelphia for the Miami company. Upon each side were also some eight or ten engineers and metallurgists, many of whom had taken part in the Hyde case.

Mr. John Ballot, head of Minerals Separation, Ltd., who had come to America some time previous to the trial, was unfortunately unable to be present, owing to serious illness. Dr. S. Gregory, managing director of the American Minerals Separation Syndicate, represented the plaintiff by his presence.

Mr. R. C. Canby, consulting metallurgist, who had introduced flotation at the Miami plant, was present throughout the suit in the interest of the Miami company, and Mr. J. Park Channing, vice-president of the Miami Copper Company, was in almost constant attend-

ance, spending the larger part of each week in Wilmington.

The arguments upon both sides were good and very interesting. As Judge Bradford said in his closing remarks, he could see from the arguments that he was not going to be able to render a decision which would please both sides.

The decision will probably not be handed down until some time in the fall.

Bakelite Suit Decision

The U. S. District Court, Eastern District of New York, has just rendered its decision in the case of General Bakelite Company versus George J. Nikolas. The decision is in favor of the General Bakelite Company, the bakelite patents in question being held valid and infringed. The case is not only of commercial importance, but very instructive in various of its legal and chemical aspects. A full review should therefore prove of considerable interest.

An infringement suit was started by the General Bakelite Company, plaintiff, against George J. Nikolas of Chicago, defendant, trading as George J. Nikolas & Company, varnish and lacquer manufacturers.

The counsels for the General Bakelite Company were Mr. Charles Neave of Fish, Richardson, Herrick & Neave, and Mr. C. P. Townsend, of Byrnes, Townsend & Brickenstein. Dr. Baekeland testified in his own behalf and also as chemical expert. Dr. Parker McIlhiney and Dr. A. H. Gotthelf testified for the plaintiff in relation to analytical work.

Judge Willard M. McEwen and Mr. William R. Rummler of Chicago acted as counsel for the defendant in conjunction with Pennie, Davis & Goldsborough of New York. Mr. K. P. McElroy of Washington acted as chemist and patent expert for the defendant in conjunction with Dr. Ludwig Saarbach of New York, and Mr. E. B. Stuart of Chicago.

The trial was conducted before Judge Thomas I. Chatfield, of the United States District Court, Eastern District of New York. The trial was held in open court and was begun on December 9, 1913. The testimony filled 1396 typewritten pages. The whole trial took about 23 days. The final argument for plaintiff was presented on February 20 to February 21, 1914. The decision was given on June 12, 1915.

The suit was started on the following United States patents:

Baekeland, "Varnish," No. 954,666, patented April 12, 1910; original application filed October 15, 1907, divided and this application filed November 22, 1909. The claims of this patent are as follows:

"1. A varnish containing a volatile organic solvent and a condensation product of a phenolic body and formaldehyde, said condensation product characterized by its capability of transformation under the action of heat into an insoluble and infusible body, and by the presence therein of a base condensing agent.

2. A varnish containing a volatile organic solvent and a condensation product of a phenolic body and formaldehyde, said condensation product characterized by its capability of transformation under the action of heat into an insoluble and infusing body, and by the presense therein of a base condensing agent in proportions not exceeding one-fifth of the equimolecular proportion of phenolic body employed."

Baekeland, "Varnish," No. 1,018,385, patented February 20, 1912, application filed March 14, 1911. The claims of this patent are as follows:

"1. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde substantially free from uncombined phenols and a solvent therefor, said solvent containing a readily volatile organic liquid, and another organic liquid which is immiscible with water but miscible with said solvent and of which the boiling point exceeds that of water.

2. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde and a solvent therefor, said solvent containing amyl alcohol and a readily volatile organic liquid.

3. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde substantially free from uncombined phenols and a solvent therefor, said solvent containing acetone and an organic liquid of which the boiling point exceeds that of water.

4. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde and a solvent therefor, said solvent containing acetone and amyl alcohol.

5. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde and a solvent therefor, said solvent containing a readily volatile organic liquid, and another organic liquid which is immiscible with water but miscible with said solvent, which is volatilizable without decomposition when heated at atmospheric pressures, and of which the boiling point exceeds that of water.

6. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde and a solvent therefor, said solvent containing acetone and an organic liquid which is volatilizable without decomposition when heated at atmospheric pressures, and of which the boiling point exceeds that of water."

Baekeland, "Varnish," No. 1,037,719, patented September 3, 1912, application filed March 14, 1911. The claims of this patent are as follows:

"1. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor, said solvent containing a liquid oxygen-compound of the aliphatic series, and a hydrocarbon.

2. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor, said solvent containing a liquid oxygen-compound of the aliphatic series, and a cyclic hydrocarbon.

3. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor, said solvent containing a liquid oxygen-compound of the aliphatic series, and a hydrocarbon of the benzol series.

4. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor, containing a liquid oxygen-compound of the aliphatic series and a hydrocarbon, and another organic body soluble in said solvent or miscible therewith.

5. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor, said solvent containing acetone and a hydrocarbon.

6. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor, said solvent containing acetone and a cyclic hydrocarbon.

7. As a new composition of matter, a varnish comprising a condensation product of phenols and formaldehyde, transformable by heat into an infusible body and a solvent therefor containing an oxygen-compound of the aliphatic series and a hydrocarbon, and Chinese oil or tung oil."

The counsel for the defendant presented no less than 47 prior patents, aside from many literature references, each one of which was alleged by the defense to contain prior disclosures; but the decision rejected all these allegations and held that the three Baekeland patents in suit are valid and infringed. The decree covers about sixty pages; it reviews carefully the details of the testimony as well as all the arguments of the defense.

From Judge Chatfield's decision we quote the following:

The testimony shows commercially successful accomplishments, as well as scientific investigation by the patentee in this country, and his appearance and testimony upon the witness stand have plainly shown mental capacity, scientific knowledge and deductive ability which would accord with and be expected as the necessary foundation for such investigations and experimental operations as those involved in practicing or advancing the art and processes set forth in the patents as to which the present litigation has arisen.

The defendant is a practical manufacturer of varnishes in the City of Chicago, who disclaims knowledge of chemistry as a science, and who testified that in the mixture and

treatment of chemicals during the manufacture of varnish, he judged the reaction and formed all his conclusions from experience and appearances, without regard to the nature of the reaction taking place.

The plaintiff alleges infringement by the sale upon the open market of certain varnishes known as bedstead filler or gold lacquer or satin A. P. lacquer, of which admitted samples have been produced by the defendant during the course of the trial.

At the outset of the case, considerable point was made of the issue of infringement, by reason of the fact that the sample produced by the plaintiff, and obtained from a store used by the defendant as an agency in Brooklyn, was claimed by the defendant to be different in appearance from anything manufactured by him. The sample was therefore disavowed by the defendant as his product. The difference in appearance was never satisfactorily explained, but the chemical analysis of the contents and the analyses of the samples produced by the defendant were such that no issue as to the actual resemblance of the defendant's commercial product and the article described by the patents exists.

The defendant, however, contends that he does not do or use anything in the manufacture of his varnish which would be an infringement of the plaintiff's patents, and, in fact, denies the use of materials which the plaintiff, from analysis of the product, contends must be employed by him. This issue will be discussed in connection with the patents of the prior art, and we will take up at once the patents in suit and the patentee's work in connection therewith.....

Then follows a systematic review of the prior art as alleged by defendant to contain disclosures annulling the patentability of the claims of the Baekeland patents, and a comparison of these disclosures, with the claims of the Baekeland patents in suit, as well as other Baekeland patents relating thereto.

It was plainly old in the art to make pyroxylin varnishes and varnishes of phenolic condensation products. But each of these varnishes, and each condensation product, had individual characteristics, and the patents in suit involve differences in the chemical process or processes of manufacture by which the particular product, claimed in the patent as novel, is to be produced.

The defendant claims that this product, to be used in the making of varnish, was nothing more than the resin which the patentee had sought to patent for use as a varnish, and he urges, therefore, that the varnish patents themselves are invalid, citing Underwood v. Gerber, 149 U. S. 224.

He attacks further Claim 1, because the patentee is said to have acquiesced in the rejection by the Patent Office of this claim when first presented.

The application for patent 942,809, which was a renewal of application 397,560, contained the claim filed upon the 15th of October, 1907, for a varnish, and the defense claims that the rejection of the varnish claims in the condensation product patent was acquiesced in by Baekeland, and that he therefore could not divide the application and restate the claim.

Examination of the file wrapper shows that this rejection was merely because of the incompatibility, under the rules of the Patent Office, of a claim for varnish in the same patent with a claim for the condensation product with which the varnish is to be made, or a claim for the method of making that product.

Claim 2 is said to be invalid in that the specifications as originally presented, and even as finally contained in the allowed patent, do not show the rule of proportion set forth in the language "not exceeding one-fifth of the equal molecular proportion of phenol body employed." During the trial much testimony was devoted to an explanation of the meaning of "equal molecular proportion" and computation of the amount of ingredients set forth in the various patents discussed in the record.

Inasmuch as there is no dispute as to the real meaning of the phrase or as to the molecular weight of the ingredients, or as to the quantity represented by one-fifth of the phenolic body expressed in terms of molecular weight, and so long as there is no dispute as to the percentage of the whole article represented thereby, we need only look to the specifications in order to find if the language of this claim corresponds to a proposition explained in the specifications.

The patentee, when referring to the use of base, and speaking of ammonia or caustic soda as an illustration, says that so small a proportion of the base as one-half per cent of the weight of phenol, that is 1/200 by weight, and in other cases an increased amount rarely reaching 10 per cent by weight of the phenol, is sufficient. This base is, however, to be calculated from that which actually remains as such in the product or the varnish and the definite proportion contained in the claim was inserted therein after the Patent Office compelled the patentee to limit his claim of invention (but not the statement of his original experimentation or his present conclusion) to matters which the Patent Office considered new over the De Laire, Story and Luft patents.

Under these circumstances, the Court cannot see why the claims should be invalid because at the time of filing the application the patentee did not sufficiently limit the language in his claims so as to avoid interference with other patents which, however, did not disclose the precise matter ultimately proving to be that intended to be claimed as invention by the applicant, and which had been in his mind from the time of his application. Thus the small amount of base which Dr. Baekeland finds would universally produce the result desired, was not disclosed by any of the prior patents, up to the time the application by Baekeland was filed.

Subsequently a certificate of addition to the Story (French) patent was filed upon the 29th day of September, 1908, and therefrom the defendant suggests that Baekeland learned how to state the claim which he had previously been trying to formulate. But the question of patentability could not rest upon literary plagiarism even if that were shown, and the testimony in the case would indicate rather that the Story addition was an attempt to secure the French rights for the same variation from the original Story patent as were being claimed by Baekeland in the United States, even if there were reason to suppose that Baekeland had seen this addition to the Story (French) patent, which was not published until February 25, 1909.

This would not prove that Story was entitled to claim the invention over that claimed by Baekeland, and if Baekeland's invention was in fact the same as that described in the Story addition, then Baekeland would be entitled, on application to the Patent Office, to have the claim issued even in substantially the same language as that described by Story.

The defendant does not show that Story was the inventor rather than Baekeland, he merely suggests that Story's patent solicitor produced a statement of the claim in such a form that Baekeland could see at once that, stated in the same way, his invention was made valid over the prior art and would meet with the approval of the Patent Office.

But, as a matter of fact, the defense does not even make out its accusation of plagiarism, as there is nothing to show that Dr. Baekeland had the Story addition before him or called to his knowledge prior to the time when he realized the way in which to make a definite statement of what he claimed as novel in his patent over the Story or De Laire patents themselves.

The defense to the second and third patents is substantially the same as that to the first, but with the added proposition that double solvents were old in the art and that the particular double solvents claimed in the third patent were in fact but a variety of those shown in the second.

As to the last proposition which is urged (that benzol or toluol with amyl alcohol would be one of the possible components referred to in the second patent, when it suggests the use of a solvent, immiscible with water and having a boiling point higher than that of water, with one of easily volatile solvents at lower temperatures) the defendant's claim is that thereby the patentee attempts double patenting or extension of the time of protection beyond that shown by the second patent. But even though the third patent should be held to cover nothing more than one of the components disclosed by the second patent, and if the third patent should therefore be void for anything more than the period protected by the second, the defendant herein would still be an infringer of the second patent and liable.

As a matter of fact, however, the third patent is not invalid in this sense. The second patent does not teach nor show the combination of a hydrocarbon with a solvent of the aliphatic series, having the qualities of and volatilizing at the temperatures described. The testimony of the expert varnish makers in the case shows that the use of these two particular solvents would be not only an accident, but substantially improbable except as a casual experiment, and the precise nature of the product covered by the third patent is shown therein to be adapted for a particular use, and would seem to be a patentable improvement over the combination described in patent number two.

We come back, therefore, to the main defenses based upon the prior art.

The defendant attempted to show non-infringement upon his own testimony that he added no base to the commercial carbolic acid and the commercial formaldehyde solution

which he employs in making his varnish. But analysis by both the defendant's and the plaintiff's experts showed the presence of ammonia by what is called the Kjeldahl method, which shows the quantity of nitrogen and accounts for any ammonia that may have been present as a part of this nitrogenous body.

By another analysis, the plaintiff's expert, whose results compared generally closely to similar analyses by the defendant's expert, found free ammonia amounting to 13/100 per cent of the solid residue. The defendant's expert failed to take into account the combination of ammonia and formaldehyde to form hexamethylenetetramine a non-volatile base from which ammonia would not be driven off by boiling with caustic soda.

The analyses further showed that the defendant's products contained pure phenol and ammonia, and the testimony of the case shows definitely that ammonia is not found in commercial carbolic acid. But orthocresol, metacresol and paracresol, as well as pyridin are found in commercial carbolic acid. Pyridin shows by the Nessler test no trace of ammonia and yet would give by the Kjeldahl test evidence of the presence of nitrogen. Likewise by the Kjeldahl method, ammonia would be found and be calculated as nitrogen.

Commercial carbolic acid is mostly cresol, with possibly a small amount of true phenol. As true phenol or hydroxybenzol reacts more easily with formaldehyde than does paracresol or orthocresol, the fact that free phenol is found in the defendant's varnish, and that no cresols were found, would indicate that the defendant's varnish was made from phenol rather than commercial carbolic acid, and that the ammonia present must have been in some form added as a base.

While the defendant has testified to certain purchases of commercial carbolic acid, and also certain purchases of crystalline phenol, he has not testified to the use of any material which would satisfactorily account for the product shown by analysis, and it must be held that he is either making a product which infringes the plaintiff's patent, and has not disclosed the methods of so doing, or that he has added some material of which he does not know the contents himself, but which contains products that do infringe the patent.

It is no defense to a charge of infringement of a patent for a product produced by some chemical process, to assert ignorance of the reactions which take place, and thus claim the right to combine substances which on analysis are shown to cause the reactions of the process leading to the patented product, and to obtain that product itself by methods shown to be those of the patent, even though never before understood until testified to upon the trial.

If a person should attempt to excuse infringement of a patent calling for the use of iron or steel in the making of a device, by suggesting that he did not know what iron or steel was, and that he merely used a hard metallic substance which he purchased from a certain manufacturer and which did the work, it can be seen where such a doctrine would lead.

The defendant also contends that the amount of base shown by the defendant's chemist is much less than the smallest amount stated in the plaintiff's patent to be sufficient to meet the discovery therein contained. But the plaintiff's expert finds ammonia approximating 13/100 per cent of the solid residue which is within the quantity referred to in the specification.

Much of the discussion raised by the defendant with reference to the validity of the patent, both from the standpoint of the disclosures in the plaintiff's former applications and patents and also in following up the suggestions of the patents of the prior art, arise from the nature of the claims and of the invention.

It will, of course, be assumed that no chemical reaction can be patented as such. A natural product, such as ordinary salt (NaCl), could not be made the basis of a patent, nor could a discovery of the chemical reactions by which salt was formed in nature, from sodium and chlorine, be patented as a process. But if artificial salt, as a chemical substance, could be distinguished from natural salt, and if some one discovered a way to make artificial salt, he could patent the method or process, if it were novel. Provided he was the first one to produce the substance, he could patent the product as something useful in commerce or in the arts.

So it is conceivable that some gum or natural substance like shellac or amber might be found, composed of phenol, formaldehyde and a base, and transformed by heat into an insoluble and infusible substance. If such a product had been known prior to the plaintiff's patents, the plaintiff could have obtained no patent, if his product was identical and indistinguishable from the natural substance, but he would have been limited to a patent for a process.

But at a time when the only product of phenol and formaldehyde, known and described *with understanding* and *definiteness*, was a permanently fusible and permanently soluble gum, the discovery of a method of rendering this product insoluble and infusible was patentable, and provided the product could be certainly identified and distinguished from the former and known products, it could be patented as well as a combination of such substances in certain relations or proportions.

If the use of an excess of formaldehyde was overcome by the use of a large amount of base, and the base in turn removed by precipitation into an acid salt, and if the product was not identifiable or was not available for any known purpose, no patent could be issued for the process (which would be mere chemical reactions) nor for the product (see Reychler and Kleebert), and certainly the combination of that product with some other substances to form a useful article like a varnish, is inconceivable.

The patents in suit are based upon the earlier patents of Baekeland for a method of producing the phenolic gum and also his patents for the condensation product produced by the patented method. But when he attempts to make a varnish which consists of a combination based upon and making use of the patentable method of preparing the condensation product, and also upon the patentable substance itself, he has a new substance which is itself patentable. As in the case of a patentable mechanical device, this consists of more than a mere aggregation of parts.

Considering the last two patents in suit for a moment, the defendant claims that they are invalid because they show merely the use of a double solvent with a gum or product which is capable of solution for varnish purposes, which is nothing more than the ordinary defense of aggregation with respect to a combination of mechanical parts. If the use of these solvents with this particular phenolic gum presents a substance having qualities that are different from those of any other compound or substance previously used for the same purpose, it is no defense to the patent to suggest that the physical or chemical processes involved in the mixing and drying or setting of the varnish are the same as those involved in the mixing, drying or setting of a varnish which would produce different results and show different qualities.

The combination disclosed in the Baekeland patents is new for varnish purposes. It has new qualities, and meets old needs in a new way. The behavior and purposes of the double solvents, and the way in which the varnish passes through the physical and chemical changes, are, of course, not patentable, any more than the suggestion that the water present is eliminated in the form of vapor would be novel or distinguish the product from other substances. If, however, water or volatile solvents are evaporated, the patentability of the combination from which the water is produced would not be affected by the age of the world's appreciation of the principle of evaporation.

So with the first patent in suit, when we consider the various patents of the prior art by which condensation products, showing either an excess of phenol or an excess of formaldehyde, or condensation by the aid of a large amount of base, or by the acidification of the base and its removal in the form of non-soluble salts, or if we consider the possibility of obtaining a huge mass of insoluble and infusible material, of irregular shape, by a violent expulsion of steam or gas and a consequent spongy or porous form of the product, or if we consider the production of an insoluble and infusible film in small quantities upon a glass plate or in a test tube, or even if we found the product such as was shown in the Story (English) patent, where, by long application of heat a reddish or red-colored film could be produced, or if we consider a condensation product which, while capable of use as a varnish, remains permanently fusible and soluble (such as that distinguished by the novolak type) we nowhere approach to the particular condensation product and the particular combination, for use as a varnish, by which it is possible to certainly, easily and accurately begin with a condensation product that in combination with certain defined solvents will produce a varnish which with *short* subjection to moderate heat will produce a colorless, infusible, insoluble and useful lacquer film of the sort desired for use in the arts and which in certain definitely specified combinations possesses the qualities required where the surface is to be subjected to the influence of an electric current, under conditions where moisture may be absorbed or encountered.

It is unnecessary to go through the patents presented in the prior art in detail.

It is sufficient to say that in none of the earlier Baekeland patents was a varnish combination disclosed which was like that in the patents in suit, even though Baekeland in some of the earlier patents taught that his particular condensation product was available as a varnish. Nor did

any of the earlier Baekeland patents or the patents of the prior art shown in circles 2 and 3, produce the infusible and insoluble substance of the Baekeland patents shown in circles 11 and 13.

The Story (English) patent, as has been seen, presented an acid, rather than a basic condensation product, in cases where pure phenol was used; a large amount of heat or long evaporation was necessary to produce the insoluble or infusible film with the reddish tinge, while the product that Story considered available for varnish purposes was that containing the acid salts.

Such other patents as those set forth in class 15 upon the diagram, present non-phenolic or non-reactive varnishes or resins which have nothing to do with the combinations of the patents in suit, except as they may use double solvents or may set forth similar chemical reactions, or may, with the knowledge of those patents, as well as of the Baekeland patents, indicate how an exchange of substance might, by employment of the same chemical reactions as before, produce the Baekeland results. But such patents are not anticipations, nor would they be infringements of the Baekeland patents in suit, and we can therefore dismiss them, as in each case they were substantially dismissed by the defendant's expert upon the trial, by saying that no one of them showed in its entirety the precise varnish or combination of any of the three patents in suit. Even if it does not require invention to trace the resemblances between these patents and the Baekeland patents in suit, or to produce similar results by substitution of known products for those products which were different in these prior art patents, and even if we do not concede to the defendant's expert invention in tracing the points of resemblance and difference, it is evident that his recognition of these points does not raise them to the dignity of defenses, nor are they anticipations of the Baekeland patents.

The doctrine of Underwood v. Gerber (supra) is presented as authority for the claim of invalidity as to the patents in suit, because it is said that in patent 942,809, Baekeland disclosed the same form of varnish resin, and that no patentable novelty is shown in merely combining that resin with a solvent to make a varnish.

The discussion already had shows the difference between the case at bar and Underwood v. Gerber (supra), where a patented or claimed product was subsequently used as an application for the surfacing of paper. But the discussion already had shows further that patent 942,809 describes merely the process or method of producing a patentable substance, while Claim 8 describes this condensation in such general form that the description in patent 954,666, of a varnish made therewith, would still be possible as a combination, even though Dr. Baekeland might not be able to patent a second time the condensation product produced by the presence of a base condensing agent in proportions not to exceed one-fifth of the equal molecular proportion of phenolic body employed after describing that condensation product in his previous patent, 942,809, for which the application was that from which the new application was divided and re-filed.

The first patent in suit was based upon the application for 942,809, was never abandoned and was not anticipated by the subsequent separate allowances of 942,809 for one of the ingredients of the new and patentable substance which was useful commercially as a varnish.

Claim 2 of patent 954,666 is therefore valid as the definite description of the combination specifically based upon the product patented in 942,809, while Claim 1 of patent 954,666 is valid as a general description of a new form of varnish which can be produced by the methods of the specification and which is in more detail identified in Claim 2.

The patents will therefore be held valid and infringed and the plaintiff may have a decree.

The Cobalt district, Canada, has recently been visited by agents of companies operating in the Gold Coast, Africa, seeking miners for service at that place.

The manufacture of ceramic wares in the United States is a matter receiving attention at this time. According to *Technical Paper* 99 issued by the Bureau of Mines, American manufacturers have an opportunity to secure domestic trade on account of conditions created by the European war. Attention is directed, however, to the fact that the standard of American production must be maintained at the highest if permanent business is to result. The restoration of European trade in this country will require much time and money, but competition may be expected as soon as European makers can again enter the field.

Court of Appeals Decision in Nickel-Chromium Resistor Suit

In the suit of the Hoskins Manufacturing Company against the General Electric Company for infringement of the A. L. Marsh patent 811,859 (Feb. 4, 1906) the District Court of the United States for the Northern District of Illinois, Eastern Division, had sustained the patent and found it to be infringed by the General Electric Company. The latter company thereupon appealed. The United States Circuit Court of Appeals for the Seventh Circuit has now affirmed the degree of the District Court and decided that "appellant's [General Electric Company's] use of the alloy [calorite] is an infringement of the Marsh patent and should be restrained."

The case was heard before Circuit Judges Baker, Kohlsaat and Mack. The decision is written by Judge Kohlsaat.

The strongest reference brought forward against the validity of the Marsh patent was that of the English patent of Emile Placet, No. 202, Nov. 21, 1896.

"This patent was not before the Examiner, nor was it known to Marsh at the time of his invention so far as the record shows. It relates to a method of introducing pure chromium into metals and alloys in a state of fusion. Speaking of pure chromium, Placet says, 'This chromium is absolutely pure. It improves all metals and alloys with which it is mixed by imparting to them the qualities peculiar to itself. It renders them harder, more resistant to shocks, tension, and friction, and also renders them more proof against the destructive action of the air, moisture, acids, and high temperatures.' 'Chromium,' he says again, 'renders metals and alloys more resistant than heretofore to high temperatures, which renders them highly suitable for the manufacture of tuyeres, hearths, fire-arms, etc.' Again he says, 'Chromium increases the electrical resistance of manganese, ferro-manganese, ferro-nickel, and other metals employed in the manufacture of conductors of high electrical resistance.' " . . .

"Appellant [General Electric Co.] sought to purchase the patent in suit, and, failing, took appellee's [Hoskins Mfg. Co.'s] said alloy of nickel and chromium and added a small quantity of manganese and 15 per cent of iron, admittedly for the purpose of coming within the alleged disclosures of the Placet patent. These additions, appellee contends, served merely as diluents and in no appreciable degree affected the characteristics of the alloy. This element is termed calorite, and contains nickel 65 per cent, iron 15 per cent, chromium 12 per cent and manganese 8 per cent. For appellee it is insisted that, for purposes of durability as an electrical resistance element, it is practically identical with its own element.

"Appellant contends that the claims in suit are narrow and must be strictly construed, that its own resistance element does not infringe the claims as they read, that, construed in the light of the prior art and the file wrapper, the claims cannot cover appellant's element, which comes within the Placet patent and Marsh's abandoned claim four, although Placet shows no alloy, used as a high resistance element, having less than 56 per cent of iron. The patent drawing is that of a rheostat, the resistance element of which is the alloy of the patent. The patentee claims a resistance element as distinguished from a material possessed of high resistivity."

From Judge Kohlsaat's opinion we quote the following extracts:

"The invention of toasters, heaters, electrical ironers and the like had begun, and it was apparent that in these as well as in the art generally the need of conductors having great durability when subjected to heat was at hand. This involved also substances which possessed the property of ductility to a degree sufficient to permit the drawing of filaments, strands, wire, etc., for use as electrical conductors. Platinum alone was then recognized as an enduring material suitable for conductors which were required to be subjected to great heat. Its cost prohibited its commercial use. Consequently the Marsh discovery was hailed as an available substitute. It was and is a most valuable resistance material. It lasts when subjected to heat from 800 deg. to 1000 deg. C. one hundred and fifty times as long as anything in the prior art, except platinum, unless Placet may be construed to have disclosed the concept, for unless

Placet anticipates Marsh's material as an electrical resistance element it is not anticipated. It will be seen from Placet's English patent that the patentee leaves it to others to ascertain by experiment products of chromium and metals in alloy suitable for high resistance and those disclosing the element of resistance to high temperatures. Placet's discoveries were before the public about eleven years before Marsh's patent was granted, from which fact it may be at least conjectured that the valuable resistance and duration properties as resistance elements which appellant finds disclosed therein, were not ostentatiously in evidence. Now, the law is well settled that in order to anticipate a later invention, the prior description must be such as to show that the article described in the patent can be certainly arrived at by following the prior description without the assistance of local knowledge or local prior use in the locality where the description is published, and without experimentation." . . .

"Placet's statements, if taken at their face value, turn out to be untrue in many cases when subjected to experiment. It is not true that when alloyed with metal, chromium always brings to the alloy its own distinctive specific properties." Illustrations are given showing that resistivity is not increased in all cases by chromium, that the melting point is not increased in all cases by chromium and that durability is not measured by resistivity.

"There are many elements which affect the efficiency of a resistance element in an electrical circuit. The melting point, while a limit to a material's electrical resistance properties as an element, is not determinative thereof. Resistance to oxidation is an important feature. These are probably the chief factors. There must also be taken into account the temperature co-efficient, the condition of the oxide scale on the resistance material as to density, electrical conductivity, volatility, uniformity of composition of resistance material, and a number of other things. The durability of the Marsh alloy at a heat of 800 deg. to 1000 deg. C., Marsh fixes at from 200 to 2000 times that of any resistance material in the prior art. Can it be supposed that Placet, had he known of its availability as an electrical resistance element, would have overlooked it? or that all those who utilized it afterwards for the manufacture of watch springs and wheels, steel, pig-iron and precision apparatus and light filament would have passed by, as of no consequence, this great substitute for platinum, had Placet suggested its value to them, or made them understand what it was? Placet could no more claim this resistance element, as disclosed by Marsh, than could Ostermann and LaCroix with their watch spring material.

"For eleven years this device of Marsh lay hidden as a gem in its Placet matrix. There it might yet be lying had not Marsh found it and made it public. Certainly it never occurred to Placet that this chromium-nickel alloy would produce a rival to platinum as a resistance element at a cost and under conditions which made it an available article of commerce." . . .

"It is evident that Placet and the other prior-art and prior-publication references fell far short of disclosing even to those skilled in the art, the subject matter of the patent in suit.

"In his argument before the Examiner, shown in the file wrapper and contents, Marsh by his attorneys says he 'does not claim to have been the first to make the alloy itself, but to have discovered that such alloys possess certain properties adapting them for a new field of usefulness.' Again appelee says, 'Some of the most important inventions have consisted in the practical application of the discovery of a new property of matter and this invention is of that class.' And again, 'The novelty of the patent in suit consists in discovering a new use for the chromium-nickel alloy in which is produced most extraordinary and unexpected results.' And again, 'the basis of the patent is the discovery that a resistance element of the composition specified is suitable for all-round use in the various situations in which such elements are desirable.' Thus, the main feature of the patent relied upon as new is the fact that Marsh found by experiment that the alloy of the patent combined with great resistivity, marvelous durability, second only to platinum, under conditions which made its production commercially practicable. Placet merely says chromium renders certain metals more resistant to high temperature, that is, it increases the melting point in some cases—a very different thing from durability. At most, he is speaking of externally applied heat, which is no criterion for durability under internally developed heat." . . .

"If this discovery is to be judged by its contribution to the electrical art, it is entitled to be held to be measurably broad within certain lines and as such entitled to a reasonable degree of equivalents—not necessarily equivalency as found in chemical structures but, as was said in Treibacher Chemische Werkes, etc., v. Roessler & Hasslacher Chemical Co.,[1] supra, equivalency in 'functional efficiency.'

"Appellant's calorite consists in substance of appelee's alloy plus 15 per cent of iron and 8 per cent of manganese. It will be remembered that the patent specification says 'Iron, on the other hand, is readily oxidizable and will not answer my purpose when alloyed with a metal of the chromium group.' Placet speaks of the beneficial effect of an alloy consisting of chromium and ferro-nickel. Appellant claims to have brought itself within this alloy and within appellee's alleged abandoned claim 4. But Placet's alloy contained not less than 56 per cent of iron. It is evident that appellee was advised of the tendency of iron to oxidation. While possessed of high resistivity and high melting point, its duration at 1000 deg. C. is only nine minutes. Manifestly, in looking for an element possessing high specific resistance, he was awake to the necessity of such an element as had also the property of high durability. Very naturally he did not want a metal which endured at 1000 deg. C. for only nine minutes. We deem it a fair deduction from the evidence that Marsh was not thinking of a diluent of iron but of iron as a substitute for nickel, as a body for his alloy. From the record it appears that for the purpose of an all around element of great specific resistivity, including the essential companion property of endurance or resistance to the encroachment of high temperature, etc., 15 per cent of iron has no appreciable effect on a chromium and nickel alloy. Iron was supposed to increase the quality of ductility. Manganese was supposed to aid in deoxidation and refining. These elements were added to appellant's alloy, after it had analyzed two specimens of appellee's material and seem to have been added in the attempt to bring calorite within the Placet description and to avoid infringement of Marsh; but as above stated, Placet's ferro-nickel alloy contained 56 per cent iron. For all practical purposes for use in electric heating and cooking appliances and other devices employing high temperatures, the two resistance elements are equivalent. The object in increasing ductility was for the purpose of facilitating the process of drawing the alloy into strips, filaments, etc.

"As a matter of fact, appellant's resistance material is to all intents and purposes identical with that of appellee's. Its resistivity, durability, melting point, temperature coefficient, resistance to oxidation, ductility and appearance, practically coincide with that of Marsh. Appellee's element is sufficiently ductile for the uses to which it is put, as shown by the Hansen diagram above alluded to. The 15 per cent of iron is apparently lost, while the manganese makes no impression. Thus it is apparent that iron and manganese serve no purpose other than as diluents and as fictitious bases upon which to construct a claim for non-meritorious distinctions between the composition of the two alloys. Neither composition is new. When applied as electrical resistance elements, the results are identical, as is the appearance of the two. There is no other dissimilarity than the presence of small and inconsequential ingredients of iron and manganese in appellant's alloy. The new use is the same."

The Western Metallurgical Field

Colorado Manganese for the Chemical Trade

What appears to be an important supply of high-grade manganese ore in the United States, suitable more for industrial uses than for making ferromanganese, is being developed in San Miguel county, Colorado. When first discovered, the ore was submitted to certain interests in the steel trade, but was subsequently found to meet the requirements of the battery and glass trades, and is now being used for such purposes. It is claimed that large shipments can be made averaging 85 per cent MnO_2, with less than 1 per cent iron. Manganese ore of this character has been imported from Turkey; but foreign shipments have been of uncertain delivery, and an opportunity appears for the creation of a good demand for a domestic product. The Colorado Manganese Mining & Smelting Company, which owns ten claims from which ore is now being shipped, expects to produce at the rate of about 750 tons per month. The property is located in Dry Creek Basin, San Miguel county, Colorado, and the ore is hauled 40 miles to the railroad at Placerville.

[1] See pages 135 and 145 of our March issue, 1915.—Editor.

Sale of Stratton's Independence

With the sale of Stratton's Independence, Ltd., to the Portland Gold Mining Company, a most interesting chapter in Cripple Creek metallurgy is closed. Stratton's discovery and development of the Independence mine was one of the brilliant features of the early days of America's premier gold district. The subsequent sale of the property to British investors brought the property into world-wide prominence. From a metallurgical point of view, however, the chief interest centers in the successful treatment of the old mine dump, estimated to contain about 1,000,000 tons of ore worth about $3 per ton. Based on an exhaustive investigation of the tonnage, value and most economic treatment of this dump, Mr. Philip Argall represented that with a cyanide mill of 10,000 tons monthly capacity, the ore could be treated at a cost of $1.50 per ton, yielding a net profit of $1 per ton. The annual reports of the company, which have been abstracted in this journal, indicate with what precision the estimates were made and how closely they were approximated by actual results during the life of the company. The estimated profits have been slightly exceeded by the actual returns to stockholders. Mr. Argall's venture was the first in the successful cyanidation of low-grade Cripple Creek ores. In general, the methods he employed have since been adopted by other companies treating those ores locally. Special methods introduced from time to time have not proved of sufficient merit to make their use permanent. The success of the venture should encourage the company to seek other problems in which the same careful preliminary investigation can show the same probable profit.

Repairing Metallurgical Furnaces with Air Guns

Recently some interest has been aroused in the proposed use of a compressed-air gun for making repairs to metallurgical furnaces in which the linings are subject to deterioration at certain points. Inquiry among western smelter metallurgists reveals the fact that the idea is now wholly new, and has been tried experimentally. Apparently the idea occurred to a number of men about the same time, each recognizing the possibility of projecting a semi-fluid mixture of refractory material against the wall where repair was needed. An air gun for this purpose was tried at the Steptoe smelter at the time Mr. Sorensen was superintendent. At the Garfield smelter a similar device was used, made of 4-in. pipe connected with air under 100-lb. pressure and a supply of silica, with the idea of carrying the latter across the furnace. A similar scheme was contemplated by Mr. D. C. Smith, at Campo Seco; but a change in smelting practice occurring before the plan could be tried, it was rendered unnecessary. The idea appeared attractive because the repair mixture could be applied directly where needed, eliminating the waste incurred in hand work.

Since smelters have generally adopted the practice of charging reverberatory furnaces along the side walls instead of through hoppers placed centrally in the roof, the necessity for repairs to the side walls of such furnaces is no longer of great importance. The point of greatest deterioration is in the roof about 20 ft. back of the burner, and when this becomes too thin the furnace is shut down and the roof rebuilt at that point. Under present conditions of operation, therefore, the air gun would find no application for reverberatory furnaces.

In copper converters and casting furnaces, however, there might be a useful field for the device, especially of the type recently patented in which a high-temperature torch is combined with the air gun. The proposed method of operation is to comminute the refractory material of which the lining is formed, and apply it continuously in small quantities at high velocity, at the same time subjecting it to incipient fusion by means of the torch combined with the gun. The result is said to be a lining which is vitreous, homogeneous and dense throughout, fused into form at a higher temperature than that at which the furnace is normally operated. The present methods of repairing basic-lined converters consists in applying a mixture of ground magnesite and water glass with a long-handled iron spoon, or by means of a tube and plunger, the former being filled with as much of the mixture as is required and the charge pushed into place by the plunger. In casting furnaces the roof requires repairs about every six months, and while the furnace is closed for these repairs, the side linings along the slag line also are patched.

The Base-Metal Situation

The stimulating effect of the zinc market on ore production and treatment is strongly in evidence. The Joplin district especially is unusually active, record prices for "jack" being established on succeeding days. For the week ended June 12, the high price of $135 per ton for 60 per cent concentrate showed an increase of $25 per ton as compared with the previous week. Special grades brought a premium of $3 per ton. Lead ore reached the record price of $75 per ton, and calamine brought $82 per ton on a basis of 40 per cent metallic zinc.

A zinc smelter at Bruce, Kan., which has been idle for eight years, is to be put in operation. At Joplin it is reported that the Joplin Separating Company is to build a small retort plant to be operated in conjunction with the concentrator. The Delta Lead and Zinc Company, which has operated a mill at Spring City, has completed a second mill of 150-tons capacity, and several mining operators have resumed work and are shipping ore to custom mills. Romantic tales are even told of feeble old men and young children culling dumps and making startling profits. The prosperity of the district extends to miners and smeltermen, wages having been advanced materially. At the Bartlesville smelters the wages of employees have been advanced 15 per cent.

Utah lead smelters are reported operating at capacity on ores already under contract. No new contracts are being made at the present market prices for lead, and those operators who have in the past refused to sign contracts will be unable to take advantage of the rise in price.

Quicksilver is being produced by the Nevada Cinnabar Company at Ione, Nev., at the rate of about sixty flasks per week, and properties in California, Nevada and Texas that were unable to operate profitably when quicksilver was quoted at $35 to $40 per flask, are reported to be resuming operations.

Company Reports

The thirteenth annual report of the **Tonopah Mining Company of Nevada**, for the year ended February 28, 1915, shows the results of milling 143,432 dry tons of ore assaying 0.246 oz. gold and 21.22 oz. silver per ton. The costs were as follows: Mining and handling dump ore, $4.40 per ton; milling, $2.96; freight, $0.74; marketing mill products, $0.41; total, $8.51 per ton. Metal losses in milling and refining amounted to $1.23 per ton, leaving a profit of $6.51 per ton. The average gross value of ore milled was $16.25. Several radical changes were made in mill operation. It was found that the filter plant was not making a satisfactory recovery of dissolved metal, and the extraction from sand product was not as good as from slime. Filter presses were con-

sidered, but the cost for a suitable plant, including changes that would have to be made for all-slime treatment, would amount to $100,000. In addition $6000 would have to be spent for additional water supply. Finally, after considering other methods, it was decided to adopt all-sliming and decantation, which was done at a cost of $38,000. Extraction has improved, resulting in the highest recoveries in the history of the plant and the lowest total costs. The reduction in cost due to the changes, during ten months of operation, amounted to 14.4 per cent. The company owns 83 1/3 per cent of the stock of the Tonopah Placers Company, operating three dredges at Breckenridge, Col. The option on property of the Eden Mining Company, Nicaragua, was exercised in January, 1915. Sufficient ore has been developed to warrant the erection of a 100-ton unit of a mill which is expected to be in operation within a year. A two-year option has been taken on the property of the Mizpah Extension Company of Tonopah. The Tonopah Placers Company dredged 2,995,256 cu. yd. of earth, producing 22,542 oz. gold and 4781 oz. silver. The value per yard was $0.155 and the cost $0.096.

The annual report of the **Tonopah Belmont Development Company** for the year ended Feb. 28, 1915, shows marked improvement in milling operations with attendant reduction in costs. The mill treated 181,424 dry tons of ore assaying 0.2336 oz. gold and 22.3 oz. silver per ton, having an average value of $16.72 per ton. Total milling cost was $2.564 as compared with $3.049 in the preceding year. The cost per ton for labor was $0.419; supplies, $1.318; power, $0.419. In the previous year the respective costs for these items were $0.462, $1.604 and $0.494. The cost per ton for chemicals was: cyanide, $0.601; zinc, $0.0737; lime, $0.0416. The average extraction of the tonnage milled was 95.78 per cent of the gold and 91.81 per cent of the silver, or a combined extraction of 92.99 per cent. Due to the more refractory nature of the ore, resulting in a greater production of concentrates, the extraction in 1914 was 1.46 per cent lower than in 1913. The use of the Belmont type steel liner for tube-mills has shown increased efficiency, and is expected to cut lining cost from $0.032 per ton for silex to about $0.0158. At the company's Millers plant the metallurgical process was changed from filtration to continuous decantation at a cost of $24,930 for reconstruction. The mill treated 44,692 dry tons of ore at a profit of $24,344, producing 1,031,745 oz. silver and 12,469 oz. gold. Before adopting the change in treatment the extraction averaged 87.45 per cent and the total milling cost was $4.034 per ton. In January, 1915, after the change had been made, the extraction was 90.05 per cent and the cost $3.766 per ton.

The Montana-Tonopah Mines Company milled during 1914 a total of 63,754 tons of ore of average value of $8.991 per ton. The mill was closed from Nov. 15 to Dec. 31, 1914, on account of the lower grade of ore and low price for silver. The following table gives detailed milling costs:

Account	Labor Cost Per Ton	Supplies Cost Per Ton	Power Cost Per Ton	Total Cost Per Ton
Crushing and conveying	$0.079	$0.021	$0.019	$0.119
Stamping	.074	.054	.147	.275
Elevating and separating	.036	.011	.031	.078
Tube milling	.039	.103	.138	.280
Concentrating	.043	.006	.007	.056
Settling	.026	.065	...	.091
Agitating	.129	.539	.104	.772
Filtering and discharging	.087	.053	.081	.221
Precipitating	.039	.076	.029	.144
Refining	.028	.043	...	.071
Water pumping	.026	.003	.013	.042
Steam heating	.060	.183	...	.243
Mechanical department	.027	.002	...	.029
Water	...	.245	...	.245
Assaying	.016	.002	...	.018
Superintendence	.050	...	...	.050
Total	$0.759	$1.406	$0.569	$2.734

The extraction by concentration was 31.2 per cent for gold and 17.8 per cent for silver; by cyanidation, 64.5 per cent for gold and 74.4 per cent for silver; total, 95.7 per cent for gold and 92.2 per cent for silver. Cyanide consumption was 2.08 lb. per ton milled, as against 3.22 lb. per ton in the preceding year. An improvement in filtering slime was made by the adoption of the Osgood filter, designed by Mr. C. G. Osgood, mill superintendent.

The Iron and Steel Market

The situation in the iron industry as a whole is a difficult one to analyze. The steel trade proper shows continued improvement. Although production and shipments of steel products have been heavier in June than in May, the shipping orders received are stated to be in excess of shipments, and with much railroad material under contract but not yet the subject of actual specifications, steel mill operations promise to be still heavier in July, probably at the best rate since 1913. Steel prices, while not sharply advancing, are showing a stiffening tendency, and judging by conditions in their own trade steel makers feel that by August, or September at the latest, the steel mills will be operating at capacity, deliveries will be falling behind and prices will be on a firm basis at above to-day's level.

In striking contrast with this situation in the steel market proper is the fact that three important markets in the general iron situation, scrap, coke and pig iron, are dull and relatively soft. There is no distinct movement in any of them, and prices obtainable are not a particle higher than in December or January. Production and shipments of Connellsville coke are running at 330,000 tons a week, against 200,000 tons a week in December, an increase of 65 per cent, but $1.50 has lately been done for spot coke and a trifle under $1.70 for second half, prices that are if anything lower than what was obtainable in December or January. For two months scrap has been less active than in January, and prices are a shade lower. In pig iron there has been only a moderate volume of business, and indications now are that buyers are covered practically to the end of the year.

The dullness and softness in coke can be attributed to the dullness and softness in pig iron. That eliminates one unknown quantity, but still leaves two unknown quantities with only one equation from which to evaluate them. The only explanation that suggests itself is that since activity in the foundry trade, resulting in activity in pig iron, usually follows an improvement in steel by an interval of no more than a few months, and has now failed when six months or more have elapsed, and since the demand for direct export material and for material for war munitions to be made in this country involves steel rather than iron, the present condition in steel is that the activity is due chiefly to direct export and war demand, affecting steel but not pig iron. This may solve pig iron, but it does not solve scrap.

Intense activity in steel, however, is bound to affect pig iron, by creating a demand for merchant iron on the part of large steel works that are adequately fixed with blast furnace capacity for ordinary requirements, but have additional iron if their mills are to operate at an overload. The steel industry might then absorb enough extra Bessemer and basic iron to make up for the dullness in foundry grades.

Steel mill operations at the close of June are estimated at fully 80 per cent of rated capacity. The Pittsburgh district is operating at more than 80 per cent, while the Chicago, southern and eastern districts, are with a few exceptions, operating at less than 80 per cent. Here

and there mills are beginning to fall behind in deliveries, particularly in merchant bars. Predictions are made that operations will continue to increase, and if they increase much more the delay in deliveries will undoubtedly bring out a latent demand, as it always does, from jobbers and manufacturing consumers, who will see the desirability of laying in stocks to make certain of maintaining their normal operations.

At what rate the steel industry really can operate is an open question. Usually it has been able, upon occasion, to operate at an overload. At present there is some doubt whether the labor supply would admit of operating at ordinary capacity.

Pig Iron

Recent developments suggest that the pig iron market has not as strong a foundation as was assumed. The buying of the past couple months has been better than in immediately preceding months, but a survey of the whole situation indicates that the ordinary buyers, the regular consumers, are fairly well covered practically to the end of the year, while a great deal of speculative iron has been bought, and some large consuming interests are known to have large stocks. One consumer of forge and foundry grades is credited with 100,000 tons lying at its various plants. The furnaces in operation may be fairly well sold up. It may even be granted that they are fully sold up to the end of the year, still justifying the observation that the furnaces operating represent no more than about 60 per cent of the merchant capacity, and raising the question, whence is demand to arise to improve the market? We quote No. 2 foundry, delivered Philadelphia, $14.25 to $14.50; f.o.b. furnace, Buffalo, $12.50 to $13; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13 to $13.25; f.o.b. Birmingham, prompt, $9.50; third quarter and second half, $9.75; at valley furnaces, 95c. higher delivered Pittsburgh; Bessemer, $13.75; basic, $12.65 to $12.75; No. 2 foundry, $12.75 to $13; gray forge, $12.50; malleable, $12.75.

Steel

Consumers are well covered for billets and sheet bars and the regular market is quiet, but with a very decided undertone of strength. The Carnegie Steel Company recently withdrew from the domestic market, and several recent export orders taken by the Steel Corporation have been placed at Chicago and Birmingham mills instead of the Carnegie mills at Pittsburgh. It is even reported that the Carnegie Steel Company has been a buyer of steel from other mills to apply on its contracts. We quote billets at $19.50 to $20 and sheet bars at $20 to $20.50, f.o.b. maker's mill, Youngstown, and 50c. to $1 higher delivered Pittsburgh, the lower quotations referring to prompt shipment and the higher to shipment over third quarter. Rods are $25, Pittsburgh.

Finished Steel

Prior to the middle of June the large mills were all quoting 1.20c. on bars, plates and shapes for prompt shipment and 1.25c. on contracts for third quarter, while several small plate mills were quoting 1.15c. and less on plates. On June 14 the Carnegie Steel Company withdrew its lower price entirely and since then the other large mills have been gradually working up to the higher level, while the small plate mills have firmed up to 1.15c. as minimum. Indications are that bars and shapes will be firm at 1.25c. for third quarter and 1.30c. for fourth quarter, while plates may work up to 1.20c. or possibly 1.25c., depending largely upon railroad buying of cars. June 15 steel boiler tubes were advanced one point or about $2 a ton. June 1 galvanized steel pipe was advanced five points and June 17 six points more, a point being nominally 95c. per net ton. Galvanized sheets have worked up to a minimum of 5.00c., with as high as 6.00c. sometimes quoted, while there are few sellers. The differential on galvanized wire, formerly 40c. per 100 lb., has advanced at various times this year until it is now 80c., with mills usually limiting the tonnage they will accept. These advances were occasioned by the flight of spelter, to 26c. to 27c. on June 4, and are based upon a spelter cost somewhat exceeding 20c., but after the high point was reached June 4, spelter began declining and crossed 20c. on June 17. Whether it will eventually find a level above or below 20c. no one ventures to guess.

Current quotations are as follows for ordinary deliveries, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.15c. to 1.25c.

Shapes, 1.25c.

Steel bars and bands, 1.25c., base; hoops, 1.25c. to 1.30c., base.

Iron bars, 1.20c. to 1.25c, Pittsburgh; 1.17½c. to 1.22½c., Philadelphia; 1.15c. to 1.20c. Chicago.

Sheets, blue annealed, 10-gage, 1.35c.; black, 28-gage, 1.75c.; galvanized, 28-gage, 5.00c. to 5.50c.; painted corrugated, 28-gage, 1.95c.; galvanized corrugated, 28-gage, 5.05c. to 5.55c.

Tin plate, $3.10 to $3.20 for 100-lb. coke.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 57½ per cent off list.

Steel boiler tubes (less than carloads), 3½ to 4½ in., 73 per cent off list.

Structural rivets, 1.50c.; boiler rivets, 1.60c.

The Western Trip and the Los Angeles and San Francisco Meetings of the American Institute of Chemical Engineers

The party of the American Institute of Chemical Engineers will leave New York on Friday, Aug. 6, via Pennsylvania Railroad at 5.04 p. m.; leave Chicago on Saturday, Aug. 7, via Santa Fé, and arrive on Monday, Aug. 9, 7 a. m., at Colorado Springs, where Monday and Tuesday will be spent (trips to Cripple Creek, Pike's Peak, etc.). The party leaves Colorado Springs on Tuesday, 6.45 p. m., and arrives at the Grand Canyon on Thursday 1.50 a. m. Thursday will be spent in sightseeing in the canyon. The train leaves Grand Canyon Thursday, 8 p. m., and arrives in San Diego on Friday, Aug. 13, 6 p. m. Saturday and Sunday will be spent in San Diego in visiting the exposition. The party leaves San Diego Sunday, 11.59 p. m., and arrives at Los Angeles on Monday, Aug. 16, 3.30 a. m.

LOS ANGELES MEETING

Monday, Tuesday and Wednesday, Aug. 16, 17, 18, will be spent in Los Angeles. For Monday a trip to Redondo Beach (oil-burning power plant), San Pedro Harbor (salt plant and kelp industry), Long Beach, Huntington Beach (beet sugar factory) and Santa Ana has been arranged, for Tuesday a trip to Catalina Islands. Monday evening the mission play at Alhambra will be visited. Various optional trips have been arranged for Wednesday, while on Wednesday evening a joint meeting will be held with the Southern California section of the American Chemical Society.

On Thursday, Aug. 19, 7.25 a. m., the party will leave Los Angeles for San Francisco. Stops will be made at Santa Barbara (or Oxnard beet sugar factory) and Del Monte and the Yosemite Valley may be visited for three days.

SAN FRANCISCO MEETING

Wednesday to Saturday, Aug. 25 to 28, will be devoted to the meeting at San Francisco. On Wednesday afternoon an excursion will be made to the Protrero oil gas works, on Saturday an excursion to the Winehaven vineyard and wineries. The program of the technical sessions is as follows:

Wednesday, Aug. 25, 11 a. m., at Civic Center Auditorium, San Francisco:

A. M. McAfee—"The Improvement of High Boiling Petroleum Oils and the Manufacture of Gasoline as a Byproduct Therefrom by the Action of Aluminium Chloride."

Arthur L. Lachman—"Wine Making."

Thursday, Aug. 26, 10 a. m., at University of California, Berkeley:

Ralph A. Gould—"Costs as Applied to Professional Businesses."

Edgar Baruch—"Resources and Possibilities of the Chemical Industry in the Southwest."

Otto Best—"Manufacture of Cream of Tartar."

Friday, Aug. 27, 10.15 a. m., at Leland Stanford University, Palo Alto:

S. W. Young—"Present State of the Thiogen Industry."

Edward Bartow—"Purification of Sewage by Aeration in Presence of Activated Sludge."

Walter A. Schmidt—"Electrical Precipitation Method."

Members of the party will have the option of going from San Francisco to Seattle either by rail or partly by steamer to attend the Seattle meeting of the American Chemical Society for one day, on Thursday, September 2. On the evening of the same day the party will start on the return trip, which includes a stop at Butte and Anaconda (Saturday and Sunday, Sept. 4 and 5), and a visit to Yellowstone Park (Monday to Saturday, Sept. 6 to 11).

The party will leave Yellowstone Park at Gardiner on Saturday, Sept. 11, 7.15 p.m., and is due in New York on Sunday, Sept. 19, 7.57 a.m.

Dr. John C. Olsen, Cooper Union, New York City, is the secretary of the Institute.

The Western Trip of the American Chemical Society

As has already been announced, the autumn meeting of the American Chemical Society will be held in Seattle, Washington, from August 31 to September 2.

The following trip by special train has been arranged to take the Eastern members to Seattle:

The train leaves *Chicago* on Thursday, August 26, at 5:05 p. m., via Chicago & Northwestern Railway, arriving at St. Paul, Minn., on August 27, at 5 a. m., and leaving 30 minutes later via Great Northern Railway. It passes through the scenic lake park country of Northern Minnesota and the immense grain fields of North Dakota and Eastern Montana.

Glacier Park Station is reached on Saturday, August 28, at 2 p. m., and Saturday afternoon and Sunday are spent in the *Glacier National Park* (automobile trip on Saturday afternoon through the Two Medicine and Cut Bank Valleys to the St. Mary Camp and launch ride on the Lake St. Mary. The night is spent at the Going-to-the-Sun Camp. On Sunday return launch ride to St. Mary Camp and automobile trip through the Sherbourne Lake country to Many Glacier Camp.)

The train leaves Glacier Park Station on Sunday afternoon (August 29) and arrives in *Seattle* on Monday afternoon, 6 p. m. Tuesday, Wednesday, and Thursday (August 31 to September 2) are spent in Seattle attending the American Chemical Society meeting.

Seattle is left on the evening of Thursday, September 2, at 11:55 p. m. The train arrives on Friday, September 3, at 4:35 a. m., at Ashford, from where the trip to the *Mount Rainier Park* is made. From the National Park Inn at Mount Rainier several side trips may be made during the day.

The train leaves Ashford the same afternoon at 4:35 and arrives in *Portland* on September 4, at 6 a. m. The whole of Saturday is allowed for sightseeing in Portland. The train leaves Portland 8:15 p. m. and is due in *San Francisco* on Sunday evening, September 5.

It is of the utmost importance for the success of this trip that the Secretary of the American Chemical Society, Dr. Charles L. Parsons, Box 505, Washington, D. C., be informed as soon as possible by those members who want to join in the trip.

Special Trains of Civil, Mining, Mechanical, and Electrical Engineers to International Engineering Congress

Two special trains have been arranged jointly by the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, in connection with the International Engineering Congress.

The first train will leave New York (Grand Central Terminal) on Thursday, September 9, at 7.45 p. m. and arrive at San Francisco on Wednesday, September 15, at 9 p. m. A 4-hour stop will be made at Niagara Falls (Sept. 10), a 12-hour stop at Colorado Springs (Sept. 12), and a 15-hour stop at the Grand Canyon, Arizona (Sept. 14).

The second train—or at least a number of special cars on the Sunset Limited—will leave New Orleans on Sunday, September 12, 11 a. m., and arrive at San Francisco on Wednesday, September 15, 1 p. m.

Members of the societies of Civil, Mining, Mechanical, Electrical Engineers and Naval Architects, whether members of the Congress or not, and members of the Congress, whether members of any of those five societies or not, will be welcome to join these special trains. Mr. Charles Warren Hunt, 220 West 57th Street, New York City, is the secretary of the joint committee on reception and transportation.

The Western Trip of the American Electrochemical Society

The Fall meeting of the American Electrochemical Society will be held in San Francisco on Thursday, Friday and Saturday, September 16, 17, 18, 1915; that is on the same dates as the meetings of the civil, electrical, mechanical, and mining engineers, and at the close of the week, immediately preceding the International Engineering Congress. Arrangements have already been made for joint sessions with the Electrical Engineers and the Mining Engineers.

Mr. J. M. Muir, 239 W. 39th Street, New York City, has been appointed chairman of the transportation committee. It is the intention to arrange a number of special cars for members and friends of the American Electrochemical Society, to go by as cool a route as possible directly to San Francisco, to arrive there on Wednesday, September 15. The return trip may be made as desired, and the stops for sight-seeing would be made on the return trip.

To those members of the American Electrochemical Society who want to include sight-seeing stops in the outgoing trip, two opportunities are afforded.

The American Chemical Society has extended a cordial invitation to members of the American Electro-

chemical Society to join in the special train which carries the former society to its meeting in Seattle. (See program, page 419.)

The special train of the four engineering societies for San Francisco may be used by those who are either members of the Mining or Electrical or Mechanical or Civil Engineers, or are members of the International Engineering Congress. (See itinerary, page 419.)

The Corrosion Problem Before the American Iron and Steel Institute

The meeting of the American Iron and Steel Institute, held in the Hotel Waldorf in New York on Friday, May 28, 1915, brought out quite a number of able and interesting papers, on "Blast Furnace Advancement," by Andrew E. Maccoun, on "Merchant Rolling Mills" by Jerome R. George, on "The Commercial Production of Sound and Homogeneous Steel" by Edward F. Kenney, on "Wash Boiler Heaters" by Charles J. Bacon, and on "Recent Progress in Corrosion Resistance" by Daniel M. Buck. The last paper elicited a long discussion.

Mr. **Daniel M. Buck,** who is metallurgical engineer of the American Sheet & Tin Plate Company, reported on several years' exposure tests of full-sized sheets, unprotected in any way, under service conditions.

"The influence on corrosion of carbon, manganese, phosphorus, and silicon in the amounts normally present in properly made steels and irons is practically negligible. In a steel without copper, high sulphur content stimulates corrosion. A copper content of 0.25 per cent materially increases the life of steel and iron, and the harmful effect of sulphur up to at least 0.14 per cent is neutralized by 0.25 per cent copper. More copper, up to 2 per cent, gives little, if any, additional benefit. Lesser amounts than 0.25 per cent have great influence in lowering the corrosion rate. A content of 0.15 per cent is in most cases quite as good as 0.25 per cent, and tests now under way prove that much lower amounts, down to as little as 0.04 per cent and 0.06 per cent, while not giving the best results, are superior to normal steels carrying only the usual traces of copper."

Dr. **Allerton S. Cushman,** director of the Institute of Industrial Research, Washington, D. C., opened the discussion, representing the opposite side. In his opinion "Mr. Buck's tests on which he bases his conclusions are open to criticism both in their conduct as well as in the interpretation of the results obtained."

"Mr. Buck in his paper sounds the warning that the benefits he claims accrue only if the copper is properly added to molten steel. About 0.2 per cent of benzoate of soda has been used to preserve and make salable very bad tomato catsup, but its presence cannot turn bad and dirty stuff into good and clean food. In my opinion, precisely the same thing is true of 0.2 per cent of copper in steel."

"At my original suggestion, the corrosion committee of the American Society for Testing Materials is about to undertake a series of systematic weather exposure tests on large corrugated sheets of 16 and 22-gauge iron and steel of all types now available in the open market. These sheets are not to be pickled and only a portion of the heavier gauge are to be sand-blasted. Until these authoritative and unbiased tests can be reported on, it is my belief that such sweeping claims as Mr. Buck has made in his paper are quite unjustified. My own opinion, based on what I consider the most reliable data yet available, is that in metals, as in food, purity is the safest criterion of excellence."

Mr. **James O. Handy,** director of the chemical laboratories of the Pittsburgh Testing Laboratory, sustained the exactness of Mr. Buck's tests.

"We feel certain that in some way the accelerating effect upon corrosion exercised by sulphur in steel is entirely inhibited by the addition of copper. The most probable theory is that copper unites with the sulphur and the copper sulphide dissolves in the excess copper, and the mixture dissolves in the steel itself. The sulphide of copper is not as readily oxidized as sulphide of iron or sulphide of manganese, and copper itself is extremely weather resistant. The steel, therefore, is far less readily oxidized than when the sulphides of iron or manganese are present in the steel."

"The critical percentage at which copper begins to control the corrosion of steel is between 0.03 per cent and 0.04 per cent. The difference is very striking. The corrosion rate is 100 per cent higher in the case of steels or irons containing less than 0.03 per cent copper, as compared with those containing over 0.04 per cent."

Dr. **Wm. H. Walker,** professor of chemical engineering of the Massachusetts Institute of Technology, emphasized that according to the electrolytic corrosion theory metal plus water yields metal hydroxide plus hydrogen; there are therefore four factors to be considered, and some adherents of the electrolytic theory err in considering only the effect of the metal and neglecting the effect of the other factors, the hydroxide and the hydrogen. A complete theory should pay attention to the influence which the other ingredients—not iron—may have on the solution pressure of the iron or upon the depolarization of the hydrogen or on the character of the iron hydroxide formed. His own experiments substantiate Buck's results. He has found that the film of iron hydroxide or rust which forms on a surface of copper steel is much denser and depolarizes much more slowly than does that on any other type of iron or steel.

Dr. **John S. Unger,** metallurgist of the Carnegie Steel Company, confirmed Mr. Buck's results on the beneficial effect of copper in steel. He believed that Mr. Buck's exposure tests were imitations of the conditions in actual practice, as far as this is possible.

Mr. **G. H. Charls,** vice-president of the American Rolling Mill Company of Middletown, Ohio, said it was "indeed very gratifying to observe that Mr. Buck has proved so conclusively in his table that No. 27-gauge pure iron has at least twice the life of steel. No one can justly accuse the author of this paper of being an ardent advocate of pure iron. This truth becomes more remarkable when you are informed that 27-gauge black pure iron is not even advocated by its producers because it cannot always be rolled satisfactorily. This is explained by the fact that pure iron is so soft, so ductile and welds so readily that the 27-gauge sheets stick fast together in rolling and are often damaged when torn apart.

"Due to the courtesy of Mr. Buck, a sheet taken from this lot which was to be tested came under my observation. In measuring the thickness of this sheet, it proved to be nearer 28 gauge than 27 gauge in many places, due to the difficulty of obtaining a uniform gauge in rolling such light material. It is therefore doubly gratifying to note the splendid record made by this light weight 27-gauge pure iron, pickled before it was tested to almost a tissue paper thickness, made under protest and against the advice of its producers and in every way unworthy of being considered a representative product by any fair-minded person.

"If under such adverse conditions pure iron outlasts steel two to one, it must be conceded that the claims made for this product have been thoroughly substantiated and sustained. This would be very welcome information to the thousands of purchasers of pure iron if they were not already aware of the intrinsic value of this product and its superiority to steel from the standpoint of resistance to corrosion."

Cyanidation of Low-Grade Sulphide Ores in Colorado—I

BY H. C. PARMELEE

Clear Creek and Gilpin Counties

On the eastern slope of the Rocky Mountains in Colorado, Clear Creek, Gilpin and Boulder form a trio of contiguous counties in which the earliest mining operations in the State began. Profitable mining and metallurgical treatment in this mineral empire date back to 1859. Since that time production has been continuous, with varying fortunes to individual operators, but on the whole successful and with great credit to the several districts and to the State. In general, the metallurgical treatment of the ores has followed the practice first established, amalgamation and concentration, or smelting. The milling practice has been the subject of unfavorable criticism, some of it warranted but much of it superficial and without a full knowledge of the economic conditions. Undoubtedly the metallurgical losses in concentration have been large; but the flotation process which is now being applied at some of the oldest mills should make possible an additional economic recovery of minerals hitherto lost.

Proposals to introduce modern cyanide practice in Gilpin and Clear Creek counties have been made periodically for the past five years. In 1911 Draper and Gross made exhaustive experiments on Gilpin county ores, the results of which indicated the possibility of successful cyanidation. In 1912 the Hudson mill at Idaho Springs added cyanidation to amalgamation and concentration. Little or no metallurgical difficulty was encountered, but for economic reasons cyanidation was abandoned. The practice was described in this journal at the time the mill was in operation.[1] In 1913 the Argo mill was constructed, and a treatment process adopted similar to that used at the Hudson. After a few months' operation, however, this plant also was closed, and it appeared as though it were impossible to apply the cyanide process profitably to Clear Creek and Gilpin ores. Nevertheless, the mill was started again under new and competent management and has been in continuous operation for eighteen months, demonstrating the metallurgical and economic success of cyanidation in this district.

Difficult Problems at the Argo Mill

It would be difficult to imagine more exacting and trying metallurgical conditions than those existing at the Argo mill. The mill is operated on a custom basis, sampling and buying ores as offered. There are no ore contracts, which would be of little value if they existed, for the ore supply comes mainly from leasers whose operations are irregular. Shipments are received in small lots ranging from 5 to 75 tons each, and averaging perhaps 15 or 29 tons. Frequently these lots are sampled and actually milled before assays can be made to determine their value. One lot may be of value mainly for its gold content, while the next is rich in silver. The ratios of concentration of successive lots may range from 2:1 to 25 or 30:1. Ores producing slime of fair settling rate follow those that are exceedingly difficult to settle, while the values of successive lots may range from $3 to $50 or more per ton. The sand tailings from some of the ores could be discarded without economic waste, and thus avoid the cost of regrinding; but in other instances the value of the sand necessitates regrinding in order to make an economic recovery.

Coupling these conditions with irregular and unexpected deliveries of ore, the necessity of satisfying the shipper by immediate sampling and settlement, and the impracticability of bedding ores in order to secure uniformity in mill feed, we find about as unfavorable conditions for cyanidation as could be imagined. Such conditions as these are unknown at a mill serving a single mine, where reasonable uniformity in quantity, quality and value of the ore can be expected, and where conditions of treatment can be determined and fixed by preliminary tests.

Preliminary testing at Argo has proved futile, for by the time the metallurgist may have discovered and solved a problem presented by a certain ore, production of that ore may cease. In view of these facts it is not surprising that the details of milling have undergone decided changes since operations first began, and even within the history of the present management. Hence, previously published accounts of the practice[2] do not adequately represent present operations.

Location and Construction

The Argo mill, shown in Fig. 1, is situated near the mouth of the Argo tunnel, from which the greater part of the ore supply comes. While the location is convenient with regard to delivery of ore, disadvantages have developed from the erection of the mill on a waste dump. In some parts the original excavation was not deep enough to insure solid foundations, with the result that subsequent settling dislocated part of the equipment, entailing additional expense and loss of time. Another difficulty developed due to uneven surfacing of the concrete mortar blocks, making it impossible to secure the mortars firmly on their foundations. This was overcome by loosening the bolts and calking the seams with oakum, after which the mortars could be held firmly on their foundations.

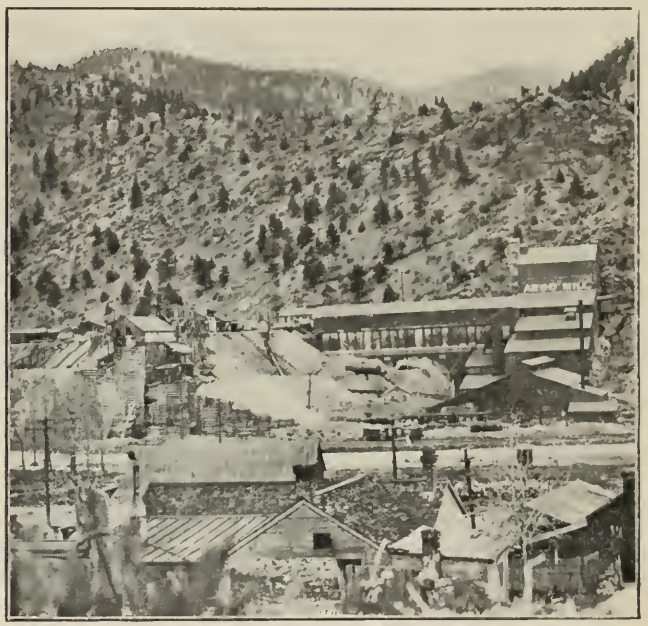


FIG. 1—THE ARGO MILL

These troubles have now been largely overcome, and in all recent work special precautions have been taken to secure solid footings. The foundation for a tube-mill recently installed is a solid concrete monolith, reinforced with steel rails with the ends bent upward into the piers which support the bearings. The mill building is of modern steel construction with concrete

[1] Cyaniding by Continuous Decantation in Clear Creek County, Colorado. H. C. Parmelee. This journal, Jan., 1912, p. 27.

[2] Ore Treatment at the Argo Mill. A. H. Roller and H. T. Curran. *Eng. & Min. Jnl.*, July 4, 1914. Cyanidation of Clear Creek and Gilpin County Sulphides. J. A. Pearce. *Min. & Sci. Press*, Nov. 28, 1914.

foundations and floors. Argon-filled tungsten lamps are used for artificial lighting and give excellent satisfaction.

Coarse Crushing and Sampling

An accurate sampling plant is necessary in order to evaluate properly the numerous lots of ore purchased. Ore is delivered in 3-ton cars, three of which can be accommodated in a revoluble tipple that traverses tracks above a series of twenty-two individual storage bins. When a shipment is completed the ore is drawn from the bin onto a pan conveyor running the full length of the bin house, and delivered to the sampling plant. The latter is of approved modern type, in which a fraction of the lot is successively crushed and split until a suitable sample is obtained. The reject passes to an elevator and is delivered directly to the battery bins by

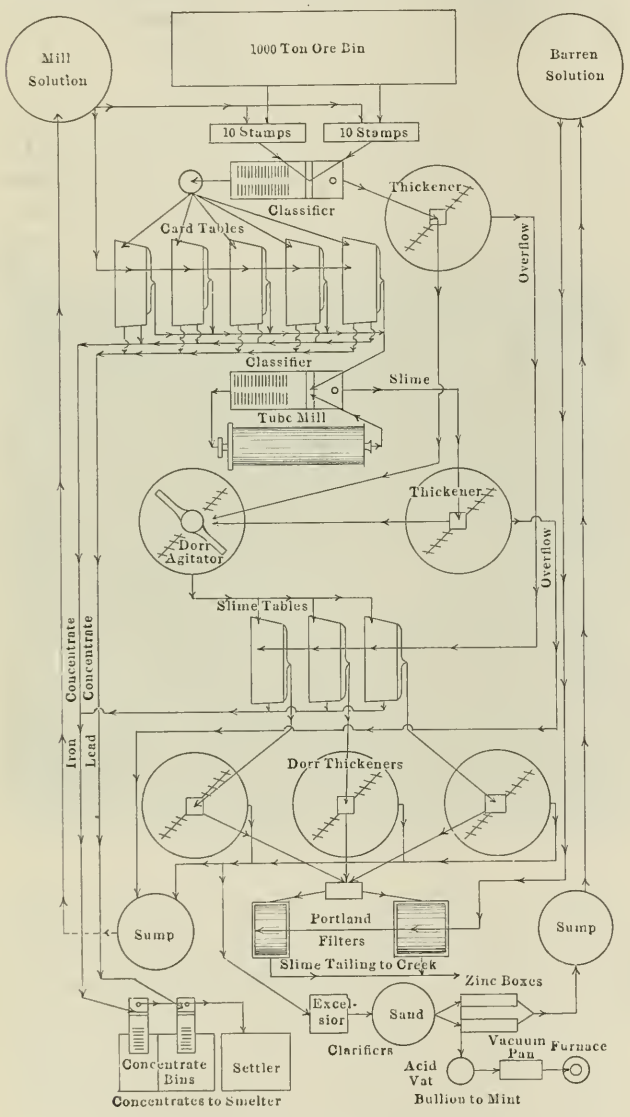


FIG. 2—FLOW-SHEET ARGO MILL

means of a conveyor and traveling tripper. This relation of the sampling plant to the mill explains why it is necessary to treat the ore as it comes, as well as the possibility of completing the treatment of a small lot before its value is known.

Flow-Sheet

The flow of the ore through the mill is outlined in Fig. 2. Briefly, the process includes stamping in cyanide solution; primary concentration to remove lead, iron and copper sulphides; regrinding the sand tailing in a tube-mill; agitation; secondary concentration to remove the sulphides unlocked in regrinding; thickening, filtration and precipitation.

The stamps are of 1050-lb. weight, dropping 108 times per minute through a height of 6 in. A heavy stamp is not required to crush those ores from which the coarse-grained sulphides are readily unlocked for concentration, while tube-milling is essential to release the minerals from the harder silicified ores. Stamp shoes and dies are of chrome steel, and the latter are sectionalized for the purpose of reducing the consumption of metal represented in discarded parts. The upper portion of the die is wedged into the lower, care being taken to get it in place evenly so that a horizontal wearing surface will be presented to the shoe. A brief experience with these sectionalized dies indicates that the upper section can be worn very thin before it is discarded. Ton-cap screens equivalent to sixteen-mesh are used on the batteries, and in crushing to this size the twenty stamps have a capacity of 120 tons per day.

The ore is crushed in cyanide solution, and the battery discharge is classified into sand and slime in a Dorr duplex classifier. The sand is treated without further classification on card tables, producing lead and iron concentrates and sand tailing. This primary concentration removes the major portion of the gold-bearing sulphides from the pulp. A secondary concentration of the slime after regrinding and agitation completes the separation of sulphides as gravity concentration can do so.

Protection of Table Decks

For the protection and preservation of the linoleum decks on the concentrating tables, a satisfactory material has been found in P & B paint diluted one-half with carbon disulphide. The paint can be used at normal consistency, but comparative tests at this mill have shown that it does not penetrate the linoleum as well as when diluted. The paint is applied hot and forms more than a mere superficial coating on the linoleum.

The lead and iron concentrates are finished products, and are dewatered, stored in bins and shipped to the smelter. The separation of the two concentrates on the tables is made with reference to their relative gold contents rather than to that of the base metals, and is governed wholly by economic considerations. The most favorable smelter rates apply to a 5-oz. gold concentrate, for which payment is made at the rate of $20 per ounce of gold. At the same time it is desirable to keep the grade of above 5 per cent lead if the most favorable treatment charge is to be obtained. Hence enough pyrite is cut into the galena to produce these conditions in the lead concentrate,and the balance is recovered as an iron concentrate carrying about 1 oz. gold per ton.

All-Sliming Following Concentration

Several methods have been in effect for the treatment following primary concentration. Originally the sand tailing was discharged as waste, being first washed with barren solution and water, and finally dewatered, in a Dorr three-deck classifier. While this practice was suitable to ores which yielded readily to concentration after coarse crushing, it was untenable with others on account of the high gold loss sustained in the finely disseminated sulphides that were not unlocked in stamping. Later a double flow-sheet was adopted, in which sand tailing from ores of the first class was washed, dewatered and discharged, while middling from the second class was reground in a tube-mill. Finally the practice was adopted of sliming all sand tailing from primary concentration, and for this purpose a new tube-mill, 5 ft. by 16 ft., was added.

The tube-mill is in closed circuit with a second Dorr duplex classifier. El Oro lining is used and the grinders

are imported Danish and French pebbles. Pebble consumption is 3.5 lb. per ton when the plant is running at full capacity, but rises with decreased tonnage.

The slime leaving this second classifier is thickened and combined with a similar product from the first classifier, and subjected to agitation. Cyanide is added at the agitator. The agitation process is continuous in a single Dorr agitator. After agitation the pulp is again concentrated, the mineral product being combined with the primary iron concentrate. The wash water used on the secondary tables is the overflow from the primary thickener, and serves to wash and dilute the pulp flowing to the final thickeners.

Diaphragm Pumps for Pulp Transfer

The transfer of slime pulp from thickeners to agitator and filters is accomplished by diaphragm pumps. The general advantages of this type of pump for maintaining uniform conditions as to quantity and density of pulp transferred have become well known. Their use in the cyanide process has led to the development of certain desirable features not usually found. An improved pump for this purpose, now in use at the Argo mill, is shown in Figs. 3 and 4, being the design of Mr. Henry Eggers of the Mine and Smelter Supply Company. It is adjustable, while running, from zero to full stroke, thus permitting an instant change in capacity without changing speed. The rocking motion usually imparted to diaphragms, and which is so destructive to long service, is eliminated by applying a vertical stroke to the diaphragm. Plunger guides and other moving parts are protected against undue wear from grit and slime. Suction may be applied from either side or from the bottom. For convenience in changing diaphragms the upper portion of the pump is hinged to the lower and can be thrown back after loosening the eye-bolts.

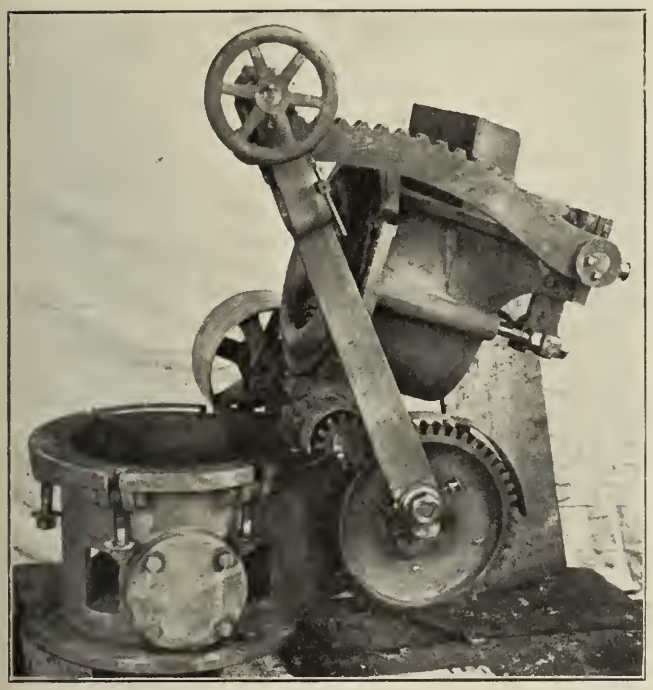


FIG. 3—DIAPHRAGM PUMP—OPEN

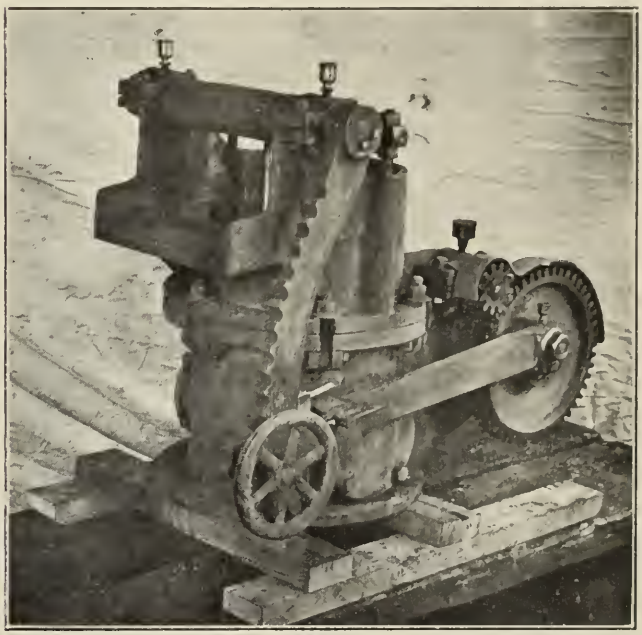


FIG. 4—DIAPHRAGM PUMP—CLOSED

Filtration of Slime

The slime tailing from secondary concentration flows to three Dorr thickeners operated in parallel. The overflowing solution is clarified and precipitated, and the thickened underflow is filtered on Portland revolving filters. Filtration was not a part of the original mill scheme, but was added by the present management after long and careful tests on the feasibility of treating these ores by continuous counter-current decantation as first attempted. As a class, the ores produce a slow-settling slime, rendering continuous decantation difficult in most cases and impossible in others, assuming a reasonable settling area per ton of material treated. This gave rise to muddy overflows and dilute underflows from the thickeners even when operated at much less than normal capacity. Considering the lack of uniformity in mill feed it is not surprising that a process which has proved so successful in many instances was not feasible here. The experience probably would have been avoided by more careful preliminary tests.

The filters give excellent satisfaction, successive washes of barren solution and water reducing the loss of dissolved gold to a negligible quantity. A vacuum of 18 or 19 in. is maintained. Little trouble is experienced in keeping the filter fabric clean and porous. Instead of giving the entire filter an acid wash at long intervals, one or two sections are treated daily with a dilute solution of hydrochloric acid, scrubbing the fabric with whiskbrooms. This method avoids the necessity of periodically removing the slime from the filter tank in order to give the entire filter an acid bath. It also eliminates acid-storage tanks and means for transferring acid solutions.

The quantity of circulating mill solution is kept constant by the addition of the requisite amount of water in the final wash on the filter.

Clarifying Solutions Before Precipitation

The marked effect of clear solutions on the efficiency of precipitation has been well exemplified at this mill. Since adopting adequate means for clarifying the pregnant solution, the earlier difficulties in precipitation have been entirely overcome. The solution flowing from the three final Dorr thickeners is passed successively through excelsior and sand clarifiers. The former consists of about 750 cu. ft. of excelsior packed in a rectangular tank having a false bottom. The solution is introduced beneath the excelsior and flows upward. The excelsior is cleaned about once in two months and re-

packed. The sand filter is about 4 ft. deep, being deeper than is usual for such purposes. Every four to six weeks a 6-in. layer of sand is removed, thoroughly washed and replaced. Previous to the adoption of these methods considerable difficulty was experienced in precipitation, chiefly in the efficiency of the operation and the grade of precipitate produced. The latter has been raised from as low as $1.50 to $40 per pound. The value of the zinc-box head solution is about $1 per ton. The tail solution has a value of about ten cents per ton.

The solution is precipitated on zinc shavings in two three-compartment boxes. No lead acetate is used, neither is any lead shaving added to the zinc. The rate of precipitation is about two tons of solution per ton of ore, when running at full mill capacity. In making the clean-up the work is done as rapidly as possible to avoid long exposure of the zinc to air. No attempt is made to effect a complete clean-up of the precious metals, as it has been found favorable to good precipitation to leave some gold on the zinc. On account of the appreciable quantities of copper in some of the ores the solution contains about 0.03 per cent copper, and this tends to lower the grade of the bullion. Until recently the bullion marketed has contained from 15 per cent to 25 per cent copper, but this has been reduced to about 1 per cent as the result of a refining process evolved by Mr. Jackson A. Pearce, metallurgist for the company. For sufficient reasons the details of the method have not yet been made public, but the benefits are very apparent.

Warm Solutions Aid Extraction

Gold and silver are the metals of principal value in the ores treated. In general, it may be said that 40 per cent of the silver in the ores is not amenable to cyanidation, but a good recovery is made by concentration. Altogether an average extraction is made of slightly over 90 per cent of the value of the gold and silver. Some lead is recovered, but there is no attempt to save zinc, nor to make an economic recovery of copper. Both of the latter metals enter into the iron concentrate.

It has been found advantageous to warm the pulp and solution to a temperature of from 60 to 65 deg. F., by means of steam coils and live steam in the thickeners. This temperature has been found to give the maximum benefit with the minimum disadvantage. It will be apparent that, with the variety of ores treated, the effect of temperature is likely to be quite as various. While extraction of silver can be increased at a higher temperature and with stronger solution, the consumption of cyanide by cupriferous ores becomes excessive. Also, the settlement of slime is variously affected by changes in temperature, being improved in the case of some ores and unfavorably affected in others.

The value of the mill feed will range from $5 to $20 per ton; and of the tailing, from $0.85 to $1. The solution in the agitator is kept at a strength of 1.7 lb. KCN per ton, with 0.8 lb. CaO.

The tonnage treated is determined by intercepting the flow of slime pulp to the filters, allowing the full stream to run into a calibrated tank for a definite time and noting the volume. Before settlement can occur, a definite volume is removed, dried and weighed, and the calculation made. This method has been found quite accurate on thick pulps, though not so well adapted to thin ones. In this case the pulp flowing to the filters contains about 1½ parts solution to 1 of solids.

Power Requirements

Electricity is the motive power used throughout the mill. A list of the motors, the machinery driven by them, and recent tests of power consumption are given below. Back-geared motors are used at the stamps.

Rated hp. of motor	Machinery driven	Horsepower consumed
25	Ten 1050-lb. stamps	22.5
50	One 5 ft. by 16 ft. tube-mill	60
5	Four diaphragm pumps, four 20 ft. by 12 ft. thickeners, one 20 ft. by 12 ft. agitator, two Portland filters, two quarter-size Dorr classifiers	2.7
5	Three Card tables, one 22 ft. by 14 ft. Dorr thickener, one duplex classifier	4.8
20	Two elevators, two conveyors and tripper	15
20	Two 12 by 10 vacuum pumps, one 5 by 8 and one 4 by 6 triplex pumps, one 1½ in. centrifugal pump	14
5	Two centrifugal pumps, three Card tables	4
25	In sampler. Pan conveyor, 4-k gyratory crusher, small jaw crusher and three sets small rolls	22

Mill Records

A system of metallurgical records devised to meet the special and varied needs at the Argo mill afford complete information regarding all operations. These are segregated under three main headings: Daily mill sheet, record of ore purchased, and record of products sold. The record sheets are 32 in. by 15 in. in size, each page serving for a month's record. The sheets are too large for reproduction in exact form, but the data can be rearranged from the following tabulations:

DAILY MILL RECORD

- Running Time
  - Hours
    - Stamps
    - Tube-Mill
  - Cause of Delay
- Tonnages
  - Solution
    - Day
  - Ore
    - Day
    - To Date
  - Slime
    - Day
    - To Date
  - Concentrate
    - To Date
- Assays, Titrations, Screen Analyses
  - Pulp
    - Battery Heads
      - Gold
      - Silver
      - Total
    - Slime
      - Gold
      - Silver
      - Total
      - —200
  - Solution
    - Zinc Box Heads
      - Gold
      - Silver
      - Total
      - KCN
      - CaO
    - Zinc Box Tails
      - Gold
      - Silver
      - Total
    - Agitator
      - KCN
      - CaO
- Specific Gravity and Temperature
  - Tube-mill discharge
    - Specific Gravity
    - Temperature °F.
  - Agitator
    - Specific Gravity
    - Temperature °F.
  - Mill
    - Temperature °F.
- Materials Used
  - KCN
  - CaO
  - Pebbles
  - Zinc
- Gross Values
  - Ore Milled
    - Day
    - To Date
  - Solution Precipitated
    - Day
    - To Date
  - Slime
    - Day
    - To Date
- Remarks

RECORD OF ORE PURCHASED

- Car Number
- Initial
- Date Shipped
- Shipper
- Mine
- Date Sampled
- Wet Tons
- Percent Moisture
- Dry Tons
- Oz. Gold per Ton
- Value Gold per Ton
- Value Gold per Oz.
- Oz. Gold in Lot
- Value Gold in Lot
- Oz. Silver per Ton
- Value Silver per Ton
- Value Silver per Oz.
- Oz. Silver in Lot
- Value Silver in Lot
- Percent Lead
- Value Lead per Ton
- Pounds Lead
- Value Lead in Lot
- Percent Copper
- Value Copper per Ton
- Pounds Copper
- Value Copper in Lot
- Percent Zinc
- Value Zinc per Ton
- Pounds Zinc
- Value Zinc in Lot
- Settlement Value per Ton
- Gross Value per Ton
- Gross Value Ore in Lot
- Deduction Silver per Ton
- Value Deduction Silver
- Treatment per Ton
- Total Amount Treatment
- Total Amount Paid for Lot
- Settlement Value Ore in Lot
- Freight Deducted
- Sampling Deducted
- Umpire Charges
- Net Proceeds
- Remarks
- Royalty Received
  - Percent
  - Amount

RECORD OF PRODUCTS SOLD

- Car Number
- Initial
- Date Shipped
- Shipped To
- Class
- Date Sampled
- Wet Tons
- Percent Moisture
- Dry Tons
- Oz. Gold per Ton
- Value Gold per Ton
- Value Gold per Oz.
- Oz. Gold in Lot
- Value Gold in Lot
- Oz. Silver per Ton
- Value Silver per Ton
- Value Silver per Oz.
- Oz. Silver in Lot
- Value Silver in Lot
- Percent Lead
- Value Lead per Ton
- Pounds Lead
- Value Lead in Lot
- Percent Copper
- Value Copper per Ton
- Pounds Copper
- Value Copper in Lot
- Percent Zinc
- Value Zinc per Ton
- Pounds Zinc
- Value Zinc in Lot
- Settlement Value per Ton
- Gross Value per Ton
- Gross Value Ore in Lot
- Deduction Silver per Ton
- Value Deduction Silver
- Treatment per Ton
- Total Amount Treatment
- Total Amount Paid for Lot
- Settlement Value Ore in Lot
- Freight Deducted
- Sampling Deducted
- Umpire Charges
- Net Proceeds
- Remarks
- Royalty Received
  - Percent
  - Amount

Tests conducted at the Argo mill indicate that the concentrates can be profitably cyanided, but at present the mill is not equipped for the work. The silver recovery probably would not exceed 60 per cent, but the gold extraction would be satisfactory. The value of the gold recovered as bullion would exceed its value in the form of concentrate, and the difference would be more than the cost of treatment. The residue from cyanide treatment would still form a low-grade shipping product, and would receive the most favorable treatment rate at the smelter. Balancing all the factors involved, the net result of cyaniding concentrates and shipping the residue to the smelter would show an increased profit as compared with the present practice of shipping direct.

The successful operation of a custom cyanide mill like the Argo depends on exhaustive preliminary tests, both chemical and physical; attention to numerous details; a careful balancing of causes and effects to secure the most economical average conditions, and last, but not least, an assured steady ore supply. The design of a new mill to meet the same conditions at Idaho Springs probably would not vary much from the present plan, which is the result of eighteen months' experience. It is likely that flotation would find a place in the flow-sheet, probably as the final step, concentrating the filter tailing. Secondary concentration after agitation could then be abandoned, and an economic advantage gained by leaving the slimed sulphides in the system to receive the maximum cyanide treatment, since gold in bullion is worth $20.67 per ounce, but only $19 per ounce in a low-grade concentrate. The cost of cyaniding would not be appreciably increased, and the flotation process would act as a final check against loss of partly extracted sulphides.

To Messrs. Richard A. Parker, consulting engineer, Ott F. Heizer, manager, and Jackson A. Pearce, superintendent, who have been responsible for the rehabilitation of the Argo mill, we are indebted for many courtesies extended in the preparation of these notes.

The Monitor Belmont Mining Co. is erecting a concentrating mill to treat silver ore valued at $10 per ton at Belmont, Nye County, Nevada. The ore will be crushed by gyratory crusher, stamps and short tube-mills, the latter being 10 ft. long by 6 ft. diameter. Coarse concentration by gravity methods will be supplemented by oil flotation.

The Testing of Materials is the title of an 89-page booklet issued by the Bureau of Standards, Washington, D. C., dealing with such subjects as metals and alloys, cements, clay products, lime, stone, paint materials, inks, paper, textiles, rubber, leather, oils, chemicals and other materials intended for technical use. The pamphlet, which contains considerable of interest, is distributed free on request.

Copper mining in Cyprus is reported to have been undertaken by an American syndicate from Arizona. Work is to be started at Skouriotissa, about 60 miles from Larnaca. Arizona mining men will compose the operating staff.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in December, 1914, was 63. The total quantity of ore milled during that period was 2,222,430 tons. There were 9807 stamps in operation, with an average duty of 9.03 tons per 24 hours. Tube mills in commission numbered 305. The yield for the month was 695,137 fine ounces gold. The total tonnage milled in 1914 was only slightly greater than in 1913. The yield for 1914 was 8,378,139 fine ounces, compared with 8,794,824 ounces in 1913.

Furnace Curves

BY R. J. WEITLANER

Every step in the direction of reducing the consumption of fuel is not only an economical saving for the individual consumer, but also for the commonwealth at large, on the principle of the conservation of our natural resources. I am referring particularly to the immense amount of fuel used in the production of iron and steel. It is to this industry that the following article is mainly devoted, although it probably has a much larger scope.

Any fuel saving must be based on an accurate account or balance sheet of the fuel consumed in a metallurgical heating or melting process. This should enable the men in charge to judge whether fuel has been saved or has been unnecessarily expended.

Having worked for quite some time on furnaces for heating and melting steel, it occurred to the writer to try to accomplish this by means of so-called "furnace curves." The results were promising, and after plotting the fuel consumption on various heating and melting furnaces, these figures could be brought into certain relations with one another.

The conclusion drawn from a great number of furnaces, covering a sufficiently long period, was that *the fuel consumption of a furnace is a function of the furnace production in a certain time-unit.*

This time-unit can be made an hour, a furnace shift, a day, a week or a month, depending more or less upon the degree of accuracy with which the amount of fuel is or can be measured during said period, and further upon the more or less great regularity with which the furnace is working in this time.

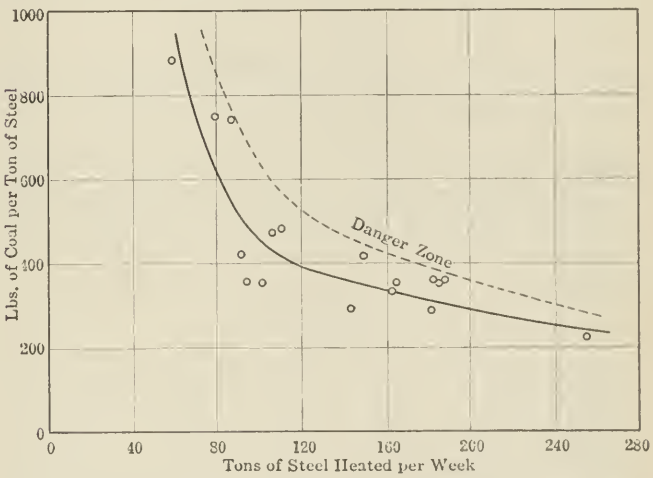


FIG. 1—FURNACE CURVE FOR COAL-FIRED HEATING FURNACE

Fig. 1 gives the furnace curve for a simple coal-fired heating furnace. The abscissas in this figure represent the tonnage produced per week, or more precisely, the tons of steel heated in this furnace during a week. The ordinates give the average fuel consumption for the same period in pounds of coal per ton (2000 lbs.) of steel heated.

Of course other units for production and fuel consumption can be chosen if more convenient as, for instance, pounds of fuel per pound of metal, etc.

The curve shown in Fig. 1 is an actual curve of a direct-fired coal furnace, and was obtained by carefully weighing the amount of coal for a number of weeks, the weekly averages being indicated by points and the curve drawn by taking the mean of all the points. Naturally all the points situated above the curve represent weeks where fuel for some reason or other was wasted:

all the points below indicate weeks where the furnace practice was better than the average.

It may, for instance, occur (see Fig. 2) that during one week we have a fuel consumption P_1 of, say, 1100 lb. per ton of steel at a weekly production of 15 tons, and during another week (P_2) the coal consumption may be 800 lb. per ton, but at a weekly tonnage of 31 tons. Yet in the first case the furnace practice was comparatively better than during the second week, as can easily be seen from the relative position of the two weekly points in reference to the average furnace curve. The saving during the first week over average practice was:

160 lb. $\times$ 15 tons = 2400 lb. of coal.

The loss during the second week amounted to:

80 lb. $\times$ 31 tons = 2480 lb. of coal.

This example should serve to illustrate the usefulness of furnace curves.

The shape of this and similar curves suggests a hyperbolic curve, and we readily see that with a smaller

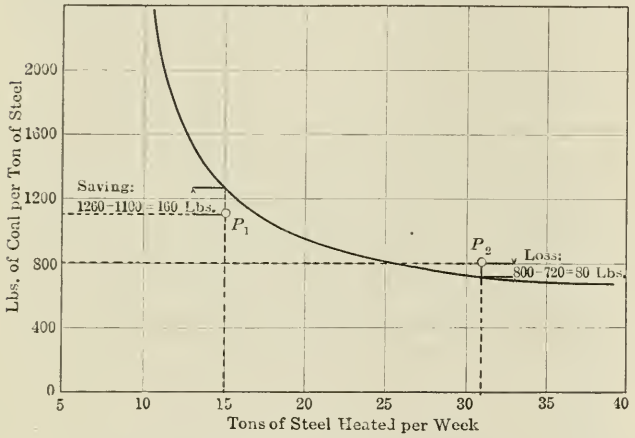


FIG. 2—FURNACE CURVE SHOWING RELATION OF FUEL CONSUMPTION TO WEEKLY OUTPUT

production the coal consumption per ton of metal increases rapidly, or, put into practical words, *we have to allow the furnace-man a higher fuel consumption for a lower production, as indicated by the shape of the curve.*

Construction and Accuracy of Curves Selection of Time Unit

Time and production units are so chosen as to give a well-shaped curve. This will especially be the case if a few points of extremely low and high production are available, that is points with simultaneous high and low fuel consumption, so that the branches of the curve are better defined. The majority of points should not be too far off from the nick or "apex" of the curve. The asymptotes are, of course, represented by the rectangular axes of the co-ordinate system (see Fig. 1).

The shape of the curve suggests at the same time at what production the furnace will work most economically; that is, we find that with decreasing production the fuel consumption increases rapidly, whereas on the other side, with a higher production, the decrease in fuel per ton becomes less and less marked.

The accuracy of the curves depends to a large degree on the accuracy with which fuel and metal is weighed or measured during a certain period. For furnaces heated by means of liquid fuel or powdered coal, where meters and automatic scales are provided, this problem becomes much easier and the resulting figures are more accurate, so that the readings should be made preferably after each twenty-four hours or better at the close of each furnace shift. By doing this we obtain a much greater number of points and the curve may be drawn with great exactness. At the same time the influence of "stray points" becomes less marked and "fake points," caused by errors in figuring, are much easier detected.

If, for instance, the fuel was stored in large piles or bins, the best we can obtain will be weekly points. At the furnace-week's end the floor or the bins will have to be cleaned up or be filled up to a certain level to obtain a fairly accurate fuel figure.

We have two ways of keeping track of the available data. Using as ordinates the fuel consumption per ton

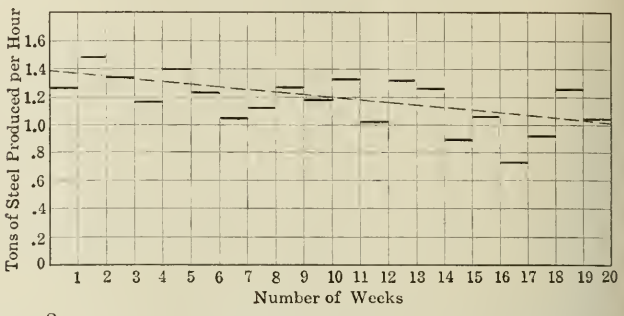


FIG. 3—INFLUENCE OF FURNACE AGE UPON PRODUCTION. ("AGE CURVE.")

of steel, we can either base it upon the entire weekly tonnage as abscissae (Figs. 1 and 2), or we divide the total tonnage by the number of hours the furnace was working and base our fuel consumption upon the tons of metal per hour (Fig. 5). In most cases this latter method will be the more accurate one, particularly if the furnace work is not continuous. With frequent intermissions of non-production or holding, it may even be necessary to deduct such fuel as was used during such intervals. In any case it will be of advantage to trace both curves, the one based upon total production, the other upon the hourly production.

Efficiency and Age Curves

If the temperature varies to which the material is heated, it will either be necessary to draw separate curves for the different temperatures or, better, to replace the fuel consumption by the term "efficiency," as outlined in the article on "comparative furnace efficiency" (see *Metallurgical and Chemical Engineering*, June, 1915, p. 357).

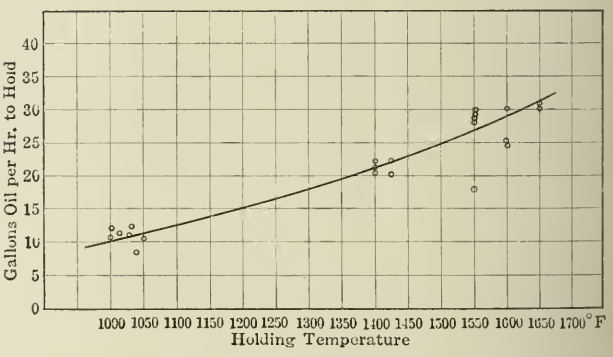


FIG. 4—INFLUENCE OF FURNACE TEMPERATURE UPON FUEL CONSUMPTION FOR OIL-FIRED HEAT-TREATMENT FURNACE

The latter method will particularly be adapted for such furnaces, where the temperature at which the metal is charged is higher than ordinary atmospheric temperature.

For melting furnaces with varying melting stock (pig iron, steel scrap, chrome scrap, etc.), either a number of "special curves" will have to be plotted, or a certain "heat content" *a* (B.t.u. per pound of metal,

see above article) will be agreed upon or determined by experiments and an efficiency curve constructed by means of it.

Such efficiency curves will also be required if, for instance, molten metal is charged into a melting furnace, although in most cases the exothermic reactions of the bath during the oxidizing period will possibly tend to cloud the fuel consumption proper.

Furnaces with a rather limited life, for example, open-hearth or crucible furnaces, will show a gradually decreasing production and increasing fuel consumption. It may sometimes be of interest to follow up this tendency by means of so-called "age curves," giving the furnace campaign week for week as abscissas and the correspondingly dropping production as ordinates (Fig. 3). It will then have to be ascertained how far the fuel consumption is influenced by the age of the furnace, besides such increases as is to be allowed on account of a lower production.

Fuel for Heating Up and Holding

Separate records should be kept of such fuel as is required to keep the furnace at a certain temperature; for instance, in heat-treatment furnaces. In this case the fuel-consumption is preferably expressed by the amount burned per hour and then made a function of the furnace temperature by means of special curves as shown in Fig. 4. Each furnace, of course, will require different amounts of fuel to be kept at a certain tem-

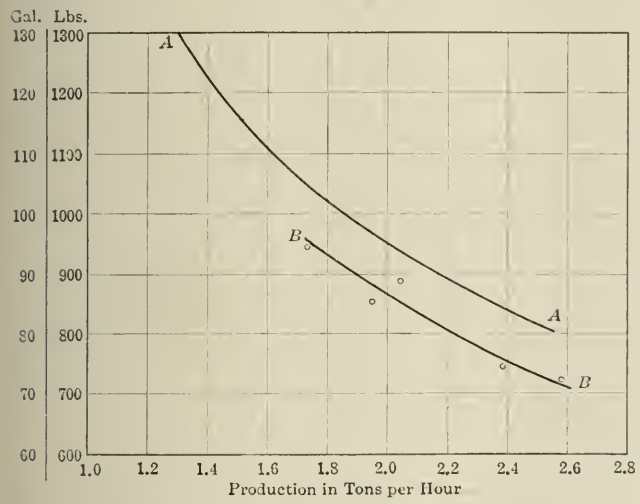


FIG. 5—COMPARATIVE COAL AND OIL CURVES FOR REGENERATIVE MELTING FURNACE OPERATED WITH PRODUCER GAS (A) OR OIL (B)

perature, depending upon the size and construction, etc., of the furnace.

If the fuel consumption per shift is kept separate and the furnace lit up every time at the beginning of the week, allowance should be made for a certain amount of fuel to be agreed on to bring the furnace up to the working temperature. A separate account should be kept of the fuel thus consumed.

Change of Fuel and Fuel Comparison

It may often occur that one and the same furnace having a well-established furnace curve is changed over to another kind of fuel. We will then find that the new fuel curve runs almost parallel to the old curve, being merely raised or lowered according to the lower or higher heating quality of the new fuel. Fig. 5 gives an idea of such curves where a furnace was changed to oil fuel after having been on producer gas for some time.

We have thus an excellent means to compare different grades of fuels as to their "thermic" value on one and the same furnace, even if the production during such periods should be at variance from points of the old fuel curve.

Fig. 6 shows a furnace curve of a coal-fired heating furnace, the average production of which with the old fuel was marked by the ordinate OP_1. The average coal consumption for this production was P_1C in pounds of

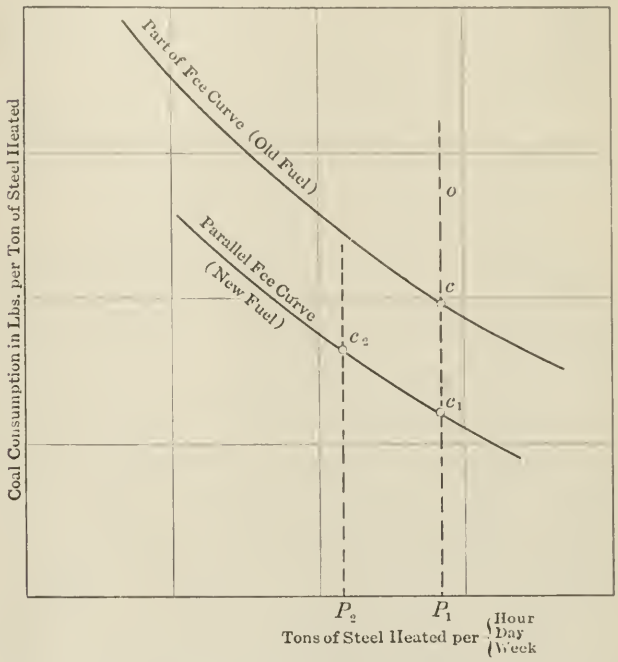


FIG. 6—FUEL COMPARISON FOR TWO DIFFERENT FUELS BY MEANS OF FURNACE CURVE

old fuel per ton of steel heated. A new fuel was introduced. The new fuel to which the furnace was changed over gave us a consumption P_2C_2 for a production OP_2 different from OP_1. Drawing through C_2 a parallel curve to the old curve we obtain C_1P_1 as the ordinate corresponding to the abscissa OP_1. The new fuel consumption, based upon the old average production (OP_1), is now represented by C_1P_1, and the distance CC_1 forms a

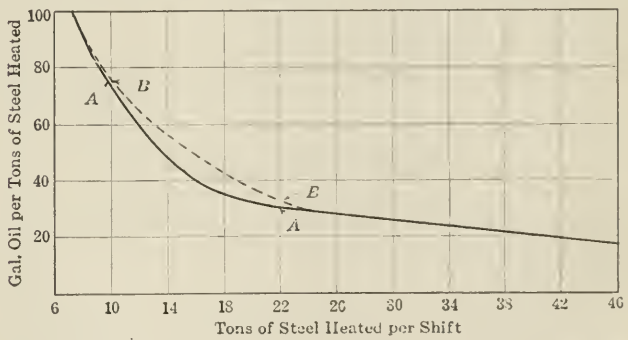


FIG. 7—COMPARATIVE FURNACE CURVES OF TWO FURNACES OF SIMILAR DESIGN—(OIL-FIRED BILLET-HEATING FURNACE)

measure of how much better the new fuel is than the original fuel. This, of course, merely indicates the heating and not the economical value of fuels, which latter shall be taken up separately.

Thus we see that with even varying production we are able to compare not only different brands of the same kind of fuel but also fuels of entire different origin.

Individual Furnace-Curves

Having constructed a certain number of furnace curves, it will soon be manifest that each furnace has

its individual curve, and that hardly two furnaces, even of apparently identical design, will have the same curve. The curves will almost always show slight variations in their fuel-consumption for varying production. This is plainly illustrated by comparing the two curves of two billet heating furnaces of similar construction, given in Fig. 7, where the fuel consumption of furnace A with a production of 10 to 20 tons per shift is decidedly lower than that of the B furnace. This may be an indication of certain slight variations in the construction of the furnaces, their stack draft, etc., which differences may have escaped notice heretofore.

In future it may be found practical to use instead of the more average fuel consumption, the characteristic furnace curves in connection with average production and fuel consumption.

Selection and Criterion of Furnaces

If a number of curves of furnaces which are not of similar construction but are used for approximately the same kind of work and production, are plotted on a sheet, using the same units for production and fuel consumption, we will notice wide discrepancies even for similar production. We therefore will try to use such furnaces which indicate the lowest consumption of fuel for certain productions if a selection of furnaces is possible.

By comparing curves of different furnaces we may even be able to draw some conclusions in regard to their construction, for instance the ratio of length to width, furnace volume, tonnage, slope, draft conditions, fire chambers, etc.

According to the curves in Fig. 7 of two similarly built billet-heating furnaces A and B, the furnace A shows a much lower fuel consumption than B at the same production. Since both furnaces were turning out same material the difference in the curves must be caused by some differences in their construction or location. In fact, certain imperfections in the location seemed to justify this conclusion.

Bonus and Cost System

After these remarks regarding the characteristics of furnace curves in general I call attention to the practical purpose for which they can be used with great advantage in my opinion.

The keeping and following-up of furnace curves seems to me the only just way upon which a bonus and penalty system should be based, if such is contemplated. We are thus able *to read off with almost theoretical exactness how much fuel was either saved or wasted* in a certain period. If expressed in dollars and cents *this system allows us to pay a certain percentage of the saving to the man responsible for the handling of the furnace or to impose penalties for any wastage of fuel.*

From the foregoing it is plain how the gains or losses expressed by the *amount* of fuel are determined. I may add that the work of keeping track of such gains or losses may be greatly facilitated if we mark on the same furnace sheets graphically the fuel costs.

If, for instance, different grades of coal and of various prices are used on a furnace, we will be able to read off the actual amounts of savings or losses in dollars and cents on the "price lines" as shown on the right side of Fig. 8. We merely draw a horizontal line through A representing 1120 lb. or ½ gr. ton of coal and measure off from A various (½) coal prices and connect with 0.0, thus obtaining price lines for any coal price. If, to give an example, one of our weekly points P should fall below the curve, we will draw two horizontal lines, through P and the ideal point P¹ of the same production (6 tons) and can now read off the actual heating or melting costs on the corresponding price lines, or as in this case on the same price line ($2.50 per gr. ton of coal) if the fuel price for P was the same as that for the curve. The difference of the two readings $0.61 — $0.50 = $0.11 tells us the cost of fuel (lost or) gained, above or below average practice.

If on a furnace, heated with oil or powdered coal, the fuel-readings can be made at the end of each furnace turn, it will be of advantage to add up all the gains and losses made by each heater, and to pay bonuses at the week's end.

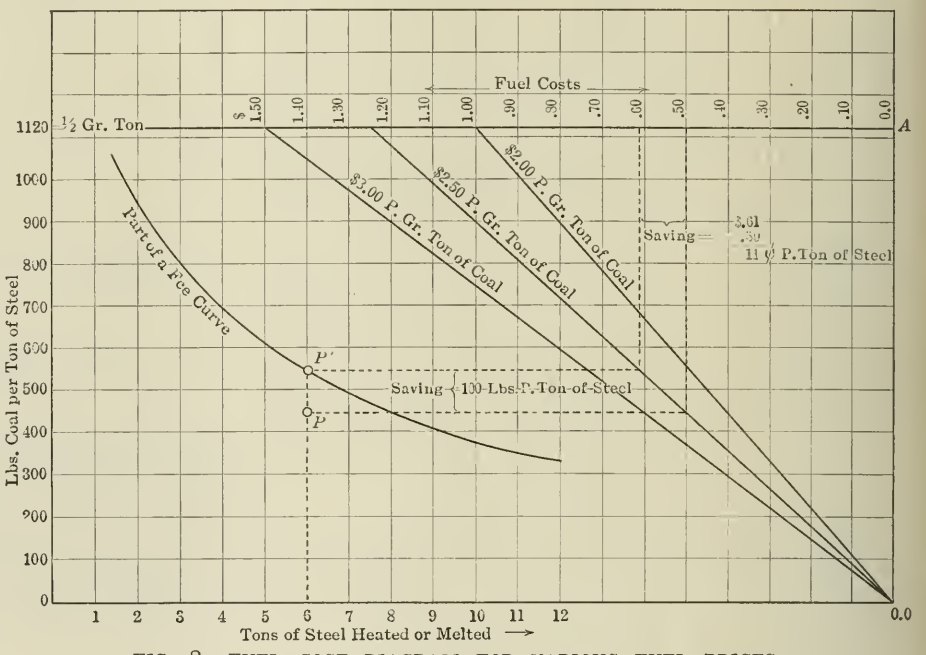


FIG. 8—FUEL COST DIAGRAM FOR VARIOUS FUEL PRICES

Should the variations from the curve be too great a so-called "danger zone" may be agreed upon, within which the points above the curve should come to fall, without imposing a penalty for such moderate losses. The dotted line in Fig. 1 suggests such a danger zone.

To sum up in the furnace curves we have a system enabling us to judge the performances of our industrial furnaces which is not only just from the manufacturer's standpoint but is also fair to the men at the furnaces.

If a furnace bonus system should be adopted and put into practice the effect will very likely be that through the endeavor of the men more and more points will come below our medium curve and thus a new improved curve will be established, which then may form the standard for future practice.

Résumé

1. Furnaces have individual curves, their fuel consumption being a function of their production in a certain time period.

2. These furnace curves should be used to determine whether fuel has been wasted or saved during a certain working period and to serve for comparing furnaces as well as fuels.

3. A bonus system can be based upon such curves.

Blast-Furnace Plant Auxiliaries and General Arrangement

BY J. E. JOHNSON, JR.

(*Continued from page* 378.)

The Dry Blast

This subject has aroused within the last ten years more comment and controversy than any other connected with the blast furnace. In dealing with the thermal principles of the furnace I shall endeavor to show that the claims for economy made on behalf of the dry blast are well founded, and in treating with the question of operation I shall endeavor to discuss the considerations other than those of fuel economy which affect the subject and must be considered before reaching a correct decision in regard to this matter. Here we have only to do with the design and construction of the plant if its installation be decided upon.

It is well known that the atmosphere contains moisture, but the laws under which the moisture exists are probably less widely understood than any others dealing with a subject which affects our daily life so much.

According to Dalton's law two or more vapors or gases can, in fact and in principle, occupy the same space at the same time, and each acts exactly as though the other were not there. That is to say, if we have two cylinders holding one cubic foot each, one of them containing nitrogen sufficient to exert a pressure of twelve and a half pounds per square inch on the inner surface of the cylinder (that is not pressure above the atmosphere but absolute pressure) and another containing oxygen sufficient to exert a pressure of two and a half pounds per square inch absolute, and pump the contents of the second cylinder into the first, each gas will continue to exert the same pressure that it did before, but in this case they will both be exerted on the walls of the same cylinder, and we shall have a nitrogen pressure of twelve and a half pounds, plus an oxygen pressure of two and a half pounds, or a total of fifteen pounds per square inch. Similarly if we have a cylinder containing a cubic foot of water vapor at an absolute pressure of half a pound per square inch, and pump that into the first cylinder we shall have a total pressure of fifteen and a half pounds per square inch, and if the cylinder were opened part of the mixture would flow out until the total pressure was down to atmospheric pressure, but the gases and the vapor would be present in the same proportions as before.

This on the assumption that the temperature is high enough to produce a vapor pressure of half a pound, and here we come into complications because the pressure of the vapor depends entirely upon the temperature, or at least is limited absolutely by it. It can never be more than the pressure corresponding to the given temperature, but it may be, and in the atmosphere generally is, less. For our present purpose it seems to me to simplify matters to consider the air not as *containing* vapor but as acting simply as a carrier for it. That is to say, if we handle ten thousand feet of air the water vapor in that air must go with it, though not in the chemical sense dissolved therein.

The determination of the quantity of moisture actually present in the atmosphere may be made in several ways. The simplest is to cool some glass or metal cup or vessel containing a thermometer by some form of artificial refrigeration very slowly, and note the temperature at which visible moisture begins to settle upon it. This is known as the dew point, and knowing this we can easily take the weight of vapor per cu. ft. directly from the vapor tables, which the United States Weather Bureau publishes in very comprehensive and satisfactory form. This, however, is not the method generally recommended for obtaining the dew point. As the result of very extensive investigations it has been stated by practically all the authorities that the wet-and-dry bulb thermometer furnishes by far the most satisfactory and reliable information. The theory of this instrument and the tables for its use have been set forth very thoroughly both in government publications and in a paper by Mr. W. H. Carrier of Buffalo before the American Society of Mechanical Engineers in Vol. 33, 1911, the latter being particularly valuable.

The quantity of moisture in air is usually given in grains per cubic foot, but this is an exceedingly unsatisfactory unit for blast furnace work because the other quantities with which we are concerned are measured in tons and pounds, but certainly never in grains, and as the effect of water vapor is purely a quantitative one it is very desirable to have it expressed in the same units as those used for other quantities involved in furnace operation. For this purpose pounds per thousand cubic feet of air are by all means the most desirable, and as there are exactly seven thousand grains in a pound avoirdupois we have only to divide the grains per cubic foot of the ordinary tables by seven to convert the results to pounds per thousand cubic feet.

Here a point of much importance arises. Air is very commonly measured at 32 deg. F., but when its temperature is raised to say 70 deg. F. its volume is increased about 8 per cent, and as the quantity of moisture increases directly as the volume, the moisture content of a cubic foot of saturated air at 70 is greater than that of the same weight of air at freezing, not only because of the increased density of the water vapor but because the carrying space in which this vapor exists is simultaneously increased.

In 1906, soon after the first announcement of the success of the dry blast, I published before the (British) Iron and Steel Institute, a paper entitled "Different Modes of Blast Refrigeration, and their Power Requirements," in which was given a chart showing the weight of water vapor per 1000 cu. ft. of air at temperatures from minus 20° to plus 80° F., but as this question of cubic feet is very troublesome, because we must always state the temperature at which the air is supposed to be measured, I converted this to 75 lb. of air which is the weight of atmospheric air at 70 deg. F. and standard barometer. This chart is shown in Fig. 2, from which it will be seen that the moisture content at saturation per 75 lb. of air rises from 0.07 lb. at zero F. to 1.14 lb. at 70 deg. F.

As normal air is about two-thirds to three-fourths saturated and as the temperature in summer may easily rise to 85 deg., it is very obvious that we have in Summer to deal with moisture sometimes reaching a pound or more per thousand cubic feet, and such is the case in many northern iron producing districts, the *average* moisture for some months being nearly a pound, while in Alabama the conditions are much worse than this, a pound and a half per thousand cubic feet being not unusual.

Accepting it as proven for the present that the action of moisture on the operation of the blast furnace is exceedingly detrimental, and realizing that the above figures indicate that we may easily be pumping 50 lb. or 60 gal. of moisture per minute into a modern furnace with the blast, the question obviously arises, how shall we eliminate it?

The metallurgical world now knows how the question was solved after many years of experiments by James Gayley at the Isabella furnaces in Pittsburg, the moisture being condensed out of the air by artificial refrigeration. Obviously, since the quantity of moisture in saturated air rises with great rapidity, with rise of temperature as shown in Fig. 1, we have only to lower

the temperature to cause the precipitation of the moisture. In practice we have to do more than this, since lowering the temperature tends to precipitate the moisture as fog, which in its form of water mechanically suspended may easily pass with the rapid current of air through the refrigerating apparatus and thus to the blowing engines and the furnace. Care must therefore be used in the design not only to condense the moisture but to precipitate it out in drops large enough to leave the air. Preferably the drops should form on the refrigerated surfaces and drip from these in such a way that the air current can not pick the drops up again.

Refrigeration requires power, and what is more serious it requires the investment of capital. Therefore it is very important to design the refrigerating plant to use the least amount of power possible since this will in general mean the smallest capital cost also, and the capital cost of this process has been its greatest disadvantage.

The original dry blast plant, that at the Isabella furnaces of the United States Steel Corporation, was of the brine circulation, single-stage type for the reason that in the vast metallurgical experiment upon which Mr. Gayley was engaged, he felt compelled to take the

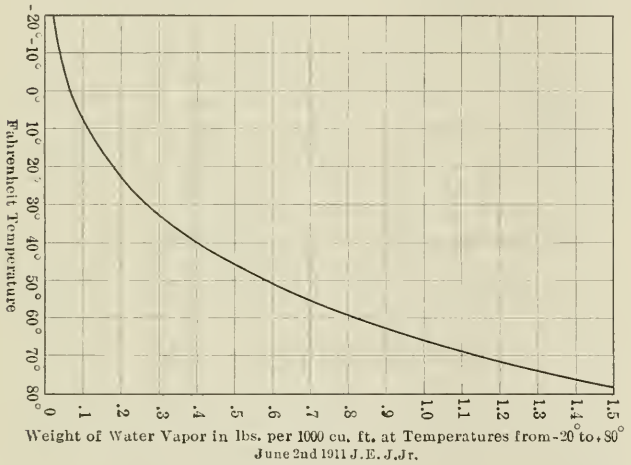

-20° -10° 0° 10° 20° 30° 40° 50° 60° 70° 80°
Fahrenheit Temperature
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5
Weight of Water Vapor in lbs. per 1000 cu. ft. at Temperatures from -20° to +80°
June 2nd 1911 J.E.J.Jr.

FIG. 2—CHART SHOWING WEIGHT OF WATER VAPOR PER THOUSAND FEET OF AIR AT SATURATION AT DIFFERENT TEMPERATURES

simplest and easiest means to accomplish the result, irrespective of whether they were the most economical, and on account of the success of this system at the Isabella plant, and of some failures of early attempts to improve upon it, the same system was used for all the early dry-blast plants. Briefly this system is as follows:

The ammonia vapor is compressed by a steam-driven compressor and condensed in a standard ammonia condenser, from which it passes to a brine cooler where it is evaporated, absorbing the necessary heat for evaporation from the brine and thereby cooling the latter. The brine, a solution of salt or calcium chloride with a freezing point many degrees lower than that of water is then circulated through other coils in a huge chamber through which the air passes on its way to the blowing engine, the air being blown into the chamber by a large fan and removed from it by the suction of the blowing cylinders. Ice forms on the coils, which soon reduces their cooling power and obstructs the passageways for the blast. This necessitates putting out of commission each of the coil chambers in turn every few days while it is thawed off by steam, an expensive operation since not only the steam but the ice cost coal, and the operation of thawing itself takes some time and labor.

A plant of this type designed by Frank C. Roberts & Co. is shown by Fig. 3. The captions under the different views render them very easy of comprehension.

A careful study of the refrigerating process makes it obvious that this system of refrigeration is capable of great improvement, both from the point of view of first cost and that of power requirements. The general principles controlling this whole matter were pointed out at some length in my paper before mentioned, part of which is reproduced below.

It is well known that the power required for a given quantity of refrigeration per minute, Q, is theoretically proportional to $\frac{T_1 - T_2}{T_1}$ where T_1 is the absolute temperature (Fahrenheit + 460 deg.) at which the heat is absorbed by the system and T_2 that at which it is rejected, the expression being

$$\text{HP} = \frac{778}{33{,}000}\ Q\ \frac{T_1 - T_2}{T_1}$$

where Q is measured in B.t.u. per minute.

The ammonia-compression refrigerating machine having so largely supplanted all others for land service, we shall consider only that type. Upon it, fortunately, reliable investigations have been made which enable us to establish a relation between its theoretical and its actual performance, and this goes far to answering our questions.

In the original paper reference was made to the work of Professor Denton in New York and Professor Schroter in Munich on tests of the power consumption of refrigerating machines, but a much more extensive series of tests have since been conducted by the York Manufacturing Company, under the direction of Mr. Thomas Shipley, their general manager, and the results of these tests have been collected and plotted in a paper on "The Power Required for Refrigeration" (*Metallurgical and Chemical Engineering*, December, 1912) and the diagram giving these results is substituted as Fig. 4. The coefficient of $\frac{T_1 - T_2}{T_1}$ based on these results becomes 3.7 instead of 4.15 corresponding to a smaller indicated power than shown in the earlier results. The difference is not great for the conditions of blast refrigeration and makes power estimates based on the subsequent curves in this quotation somewhat high and correspondingly safe.

Tests on both wet and dry compression were given in the original paper but now the dry is so much superior that the wet compression tests have been dropped and allusions to them omitted.

For a number of tests in each of these series I have calculated the theoretical horse-power by equation (1), and compared it with the actual indicated horse-power of the steam cylinders, the ratio of the latter to the former being called R, it being, in fact, the reciprocal of the efficiency on this basis.

These values of R have been plotted as ordinates with the corresponding values of $\frac{T_1 - T_2}{T_1}$ as abscissas, as shown on Fig. 4.

The values of R plainly decrease with the value of $\frac{T_1 - T_2}{T_1}$, and it is clear that when the temperature range is zero, R should be 1, the efficiency being perfect. Accordingly, a straight line has been drawn passing through the point $\left(\frac{T_1 - T_2}{T_1} = 0, R = 1\right)$ and this line coincides with the points with surprising accuracy, and may be taken as expressing the law of this relation correctly.

As these tests represent widely varying conditions in

each series, it is clear that there is a trustworthy connection between the conditions of refrigeration and the power required for it in any case.*

obviously the most convenient basis, but we are at once confronted with the difficulty that, as we change the temperature of the air, we change the volume of a given

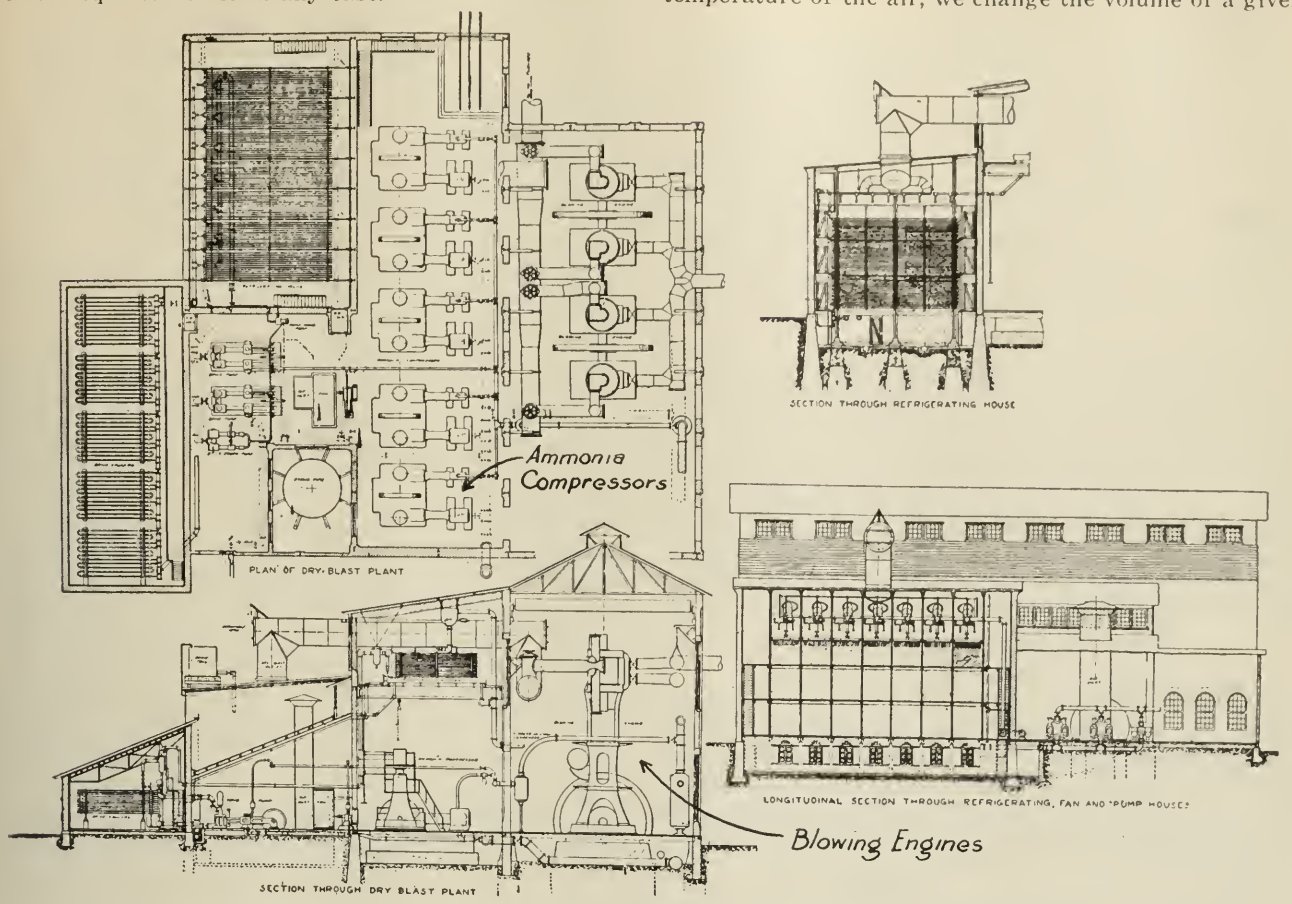

Ammonia Compressors
PLAN OF DRY-BLAST PLANT
SECTION THROUGH REFRIGERATING HOUSE
LONGITUDINAL SECTION THROUGH REFRIGERATING, FAN AND PUMP HOUSES
Blowing Engines
SECTION THROUGH DRY BLAST PLANT

FIG. 3—DRY-BLAST PLANT DESIGNED BY FRANK C. ROBERTS & COMPANY, SINGLE-STAGE, BRINE-CIRCULATION, NON-REGENERATIVE

The algebraic expression of these values is

$$R = 1 + 4.15 \frac{T_1 - T_2}{T_1}.$$

The relation between temperature range and power requirements for a given quantity of heat having been determined, we need only to know in addition the quantity of heat to be removed to determine the actual horsepower required.

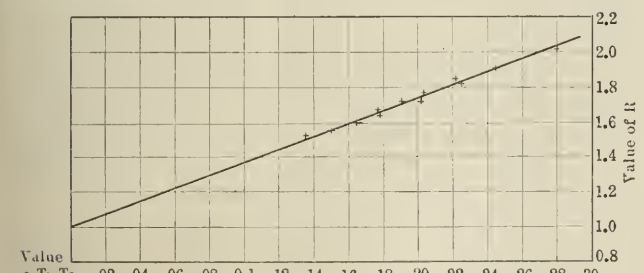

2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Value of R
Value of $\frac{T_1-T_2}{T_1}$
.02 .04 .06 .08 0.1 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30
R = Ratio of I.H.P. of Steam Cylinder of Ammonia Compressor to Theoretic or Thermodynamic H.P., for different Values of $\frac{T_1-T_2}{T_1}$
Platted from Shipley's Tests at York
June 1912

FIG. 4—CHART SHOWING RATIO OF ACTUAL TO THEORETICAL HORSE-POWER REQUIRED FOR REFRIGERATION WITH DIFFERENT TEMPERATURE RANGES

The quantity of blast used being commonly measured in thousands of cubic feet per minute, the quantity of heat required to be removed per 1000 cu. ft. of blast is

weight as well, 1000 cu. ft. at 70 deg. F., becoming 900 cu. ft. at 21 deg. F.; so that in considering the quantity of water-vapor contained in the blast as affected by refrigeration we not only diminish it by the fact that a cubic foot of space will contain less moisture at 21 deg. F. than at 70 deg. F., for instance, but that there are only nine-tenths as many cubic feet for a given weight of blast.

To overcome this difficulty the standard temperature at which blast is measured is taken at 70 deg. F., at which 1000 cubic feet of air weigh exactly 75 lbs., and all calculations are based on 75 lbs. of air, correction being made for variation in volume.

For the convenience of those desiring to make calculations on blast drying, a diagram (Fig. 5) is given herewith, which gives various relations of this standard quantity of air, based on its temperature.

The lower half of the diagram contains three curves whose abscissæ are temperatures, and their ordinates quantities of heat above 0 deg. F.

The straight line I shows the sensible heat, above that at 0 deg. F., of 75 lbs. of air at any given temperature.

The upper curve gives the quantity of heat present above 0 deg. F. in the water-vapor which will saturate 75 lbs. of air at different temperatures.

The latter quantity is not that given in steam tables as the "total heat of steam," but represents as nearly as may be the heat which would require to be removed by refrigeration in order to reduce the vapor present in the air to the quantity sufficient for its saturation at 0 deg. F.

This is made up as follows, for temperatures up to the freezing point:

*Although this seems such an obvious means of determining the actual power requirements in any case, when the general conditions are known, it is entirely new, and has never been used by refrigerating engineers, so far as known to me.

1. The sensible heat of the ice above 0 deg. F. (the specific heat taken as 0.50).
2. The latent heat of freezing.
3. The heat of vaporization.

These are all to be taken for the given temperature and the quantity of moisture actually present in 75 lbs. of air at that temperature.

Above the freezing point the conditions are altered; for part of the water, as soon as condensed, will not wait to be cooled down to the temperature of the refrigerating coils, but will drip off them soon after its deposition. As a fair estimate, therefore, one-half of the sensible heat (above 32 deg. F.) for all the vapor in excess of that present at freezing is added to the other items.

This is shown in the diagram curve II.

The lower curve III is located by adding the ordinates of the first two and represents, therefore, all the heat requiring to be removed to reduce the air from saturation at a higher temperature to saturation at 0 deg.

The small quantities of heat $\triangle Q$, of which these larger quantities are made up, are each removed at a different temperature, and therefore correspond to a different T_1, in formula (I); hence these total quantities cannot be applied directly in that formula, but the latter must be put into the form

$$HP = R \frac{778}{33{,}000} \triangle \left(\frac{T_1 - T_2}{T_2} \right)$$

and integrated in order to give numerical results. This would be so tedious a process as to be useless if done analytically, but may be done conveniently by the application of the entropy diagram invented by Professor J. Willard Gibbs of Yale University many years since, and brought to the attention of the engineering world at large some fifteen years ago by Mr. Macfarlane Gray of England.

To many it will be a matter of indifference how the results are reached, provided only that they are reached correctly and swiftly. To these it may be said that entropy is a mathematical quantity depending upon heat and temperature such that, when any thermal operation is plotted with temperature for abscissæ and entropy for ordinates, the mechanical work involved is represented by the area included, precisely as it is with coordinates of pressure and volume in the ordinary indicator-diagram. This quantity has been determined for 75 lb. of dry air, for the vapor contained in it, and for the sum of these, exactly as for the corresponding quantities of heat, and these are plotted on the upper side of the same temperature axis as the latter. These curves are numbered respectively IV, V and VI.

The theoretical or perfect cycle of operations of the ammonia compression machine is represented on this diagram by a rectangle whose right-hand end is the ordinate at the condensing temperature of the ammonia. Its top is a horizontal line at a height determined by the total entropy of the air to be refrigerated, and its bottom one at a height determined by the entropy after refrigeration. (These will be called hereafter the lines of maximum and minimum entropy respectively.) Its left-hand end is determined by the suction or absorption temperature of the ammonia, which must be low enough to absorb heat from the air at the lowest temperature to which the latter is to be reduced. In practice the suction temperature is never less than 10 deg. F. lower than this; and similarly the compression or condenser temperature is never less than 10 deg. higher than that of the condensing water.

Under normal conditions cooling water at 70 deg. F. to 75 deg. F. will always be available for condensing purposes in hot weather, and the maximum condenser temperature used in these diagrams is accordingly 85 deg. F.; also, in all the cases taken for analysis in this article, this is the condenser temperature assumed, unless otherwise stated.

If we assume a uniform difference of temperature of 10 deg. on the two sides of the expansion coils, we might construct a curve lying uniformly 10 deg. F. to the left of the total entropy curve, that is, having a temperature 10 deg. F. lower for the same ordinate in each case, and the lower left-hand corner of every rectangle would lie on this line, thus determining the rectangle completely, as the top and bottom lines are in all cases the lines of maximum and minimum entropy, and the right-hand end is the condenser temperature as before, the left-hand end being then determined by the intersection of the line of minimum entropy with the proposed curve.

This curve, however, is not drawn on Fig. 5 for the reason that the area of the rectangle so determined would have to be multiplied by R, which would have to be determined from the absorption and condenser temperature in each case, in order to give the actual power required.

In order to avoid this necessity three auxiliary curves are plotted in dotted lines, which give the actual power requirements direct, with an assumed temperature difference in all cases of 10 deg. F. at the refrigerating coils, and with three different condenser temperatures, respectively 85 deg. F., 70 deg. F., and 55 deg. F., corresponding to the temperature of cooling water available under different conditions and at different seasons.

The simple rule for the use of these curves is: Draw the lines of maximum and minimum entropy, both extending to the proper condenser temperature on the right, and the latter extending to the left to its intersection with the corresponding dotted curve; at this point erect the vertical which completes the rectangle. The area of this rectangle in square inches gives the horse-power required per 75 lb. of air for refrigeration between the limits chosen.

At various heights on the diagram the difference in temperature between the entropy curve and the assumed condenser temperature is taken, increased by 10 deg. F., and the sum multiplied by R as determined from $\frac{T_1 - T_2}{T_1}$ for that point. This product is not in any way to be considered as a temperature, but only as a length, and is set off to the left of the condenser temperature used, with the ordinate for which the temperature difference was taken.

These points are connected by the dotted curves, and when the left end of the rectangle is drawn upward from the intersection of lines of minimum entropy with the appropriate curve, its right end and top being, as before, the condenser temperature chosen and the line of maximum entropy, it is evident that the length (and therefore the area) of the rectangle has been increased in the ratio R, thus giving actual horse-power.

In using these curves care must be taken to use the one corresponding to the condenser pressure in the given case. If this be different from any of those given, the curve corresponding can be interpolated by eye with all the accuracy necessary for most purposes.

It must also be noted that the curves are only correct for the "direct expansion" system, that is to say, where the ammonia is expanded in the coils over which the air passes.

In the brine-circulation system the ammonia is expanded in coils immersed in a tank of brine, which is afterwards circulated through coils in the refrigeration chamber.

It is obvious that this system requires twice the expense for coils or pipe surface, and also requires twice

the temperature-interval between the temperature of the expanding ammonia and that of the air, required by the direct-expansion system, since the heat requires to be transmitted through the walls of two sets of pipes instead of one.

It is for the latter reason that the curves given are not correct for the brine system. To make them correct for this case at least 20 deg. F. should be added, instead of 10 deg. F., to the difference of temperature between the points on the entropy curve and the condenser temperature. This of course would give a new value of $\frac{T_1 - T_2}{T_2}$ and a new and larger value of R to correspond, so that the length of the rectangle for this case would be very materially augmented.

This, of course, means that the power required would

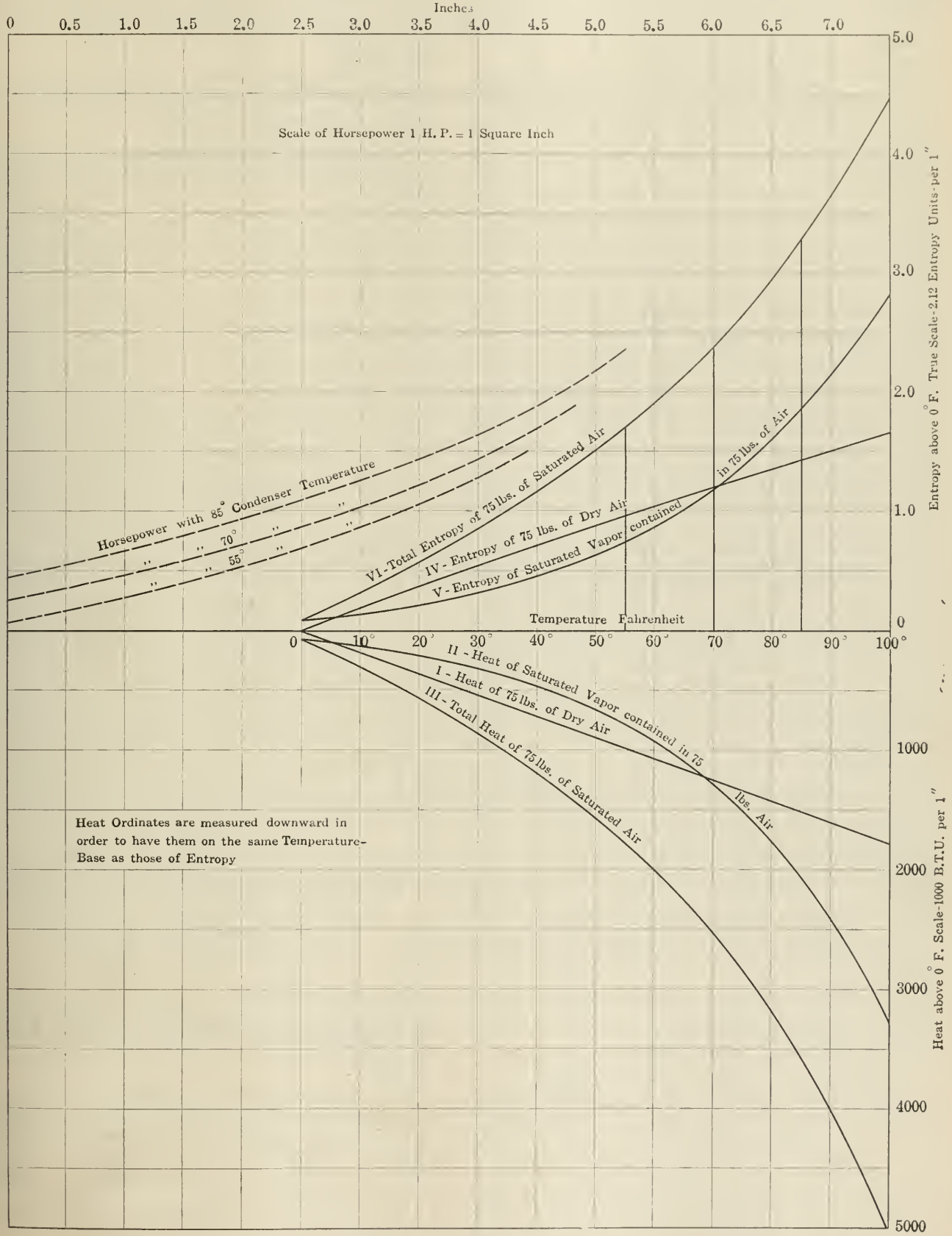

Inches
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0
Scale of Horsepower 1 H. P. = 1 Square Inch
Horsepower with 85° Condenser Temperature
" " 70° " "
" " 55° " "
VI - Total Entropy of 75 lbs. of Saturated Air
IV - Entropy of 75 lbs. of Dry Air
V - Entropy of Saturated Vapor contained in 75 lbs. of Air
Temperature Fahrenheit
0 10° 20° 30° 40° 50° 60° 70° 80° 90° 100°
II - Heat of Saturated Vapor contained in 75 lbs. Air
I - Heat of 75 lbs. of Dry Air
III - Total Heat of 75 lbs. of Saturated Air
Heat Ordinates are measured downward in order to have them on the same Temperature-Base as those of Entropy
5.0 4.0 3.0 2.0 1.0 0
Entropy above 0° F. True Scale-2.12 Entropy Units per 1"
1000 2000 3000 4000 5000
Heat above 0° F. Scale-1000 B.T.U. per 1"

FIG. 5—TOTAL HEAT AND TEMPERATURE ENTROPY DIAGRAM OF AIR AND WATER VAPOR

be augmented in the same degree, and the cost of equipment in the same degree also, or even more, owing to the high cost of the second set of cooling coils in addition to the increased compressor capacity required.

The danger to persons in the cooling chamber, from the escape of ammonia in direct expansion, is a minimum, since no one is ever required to enter it during operation and but seldom at any time; the danger of explosive mixtures of ammonia with air does not exist, and the charge would be no more irrevocably lost in the blast in the cooling chamber than in the brine tank, in case of a bad break in the coils.

Only one possible danger exists, which is, that brass parts in the path of the blast would be rapidly destroyed if persistent leaks of ammonia occurred; but as the use of brass or bronze in such a situation is unusual and may readily be avoided altogether this is not a serious matter.

Under all circumstances there does not seem to be a sufficient reason for the use of the brine circulation now that the process of blast-drying is an established success and the need for the precautions required in an experimental plant no longer exists.

It is my conviction that, for the reason given above, the eventual progress of blast-drying will be along the lines of direct-expansion, and the curves of Fig. 5 have, therefore, been calculated on this basis. Should any one desire them for brine circulation they can readily be calculated from the entropy table given and the formula for the value of R using a temperature difference for heat-transmission of 20 deg. F. or 25 deg. F., as might be found most consonant with the results of other experience with brine-circulation systems.

It might be as well to point out that the "total entropy" curve does not give the entropy for anything but saturated air; if the air be not saturated (as it generally is not), it is necessary to know both the dew-point and the temperature in order to determine the entropy. In that case the entropy of the water-vapor alone at its dew-point must be taken from the "entropy of vapor" curve and added to the entropy of the air at its temperature, as taken from the "entropy of dry-air" curve. This is most conveniently done with dividers. The total entropy so determined will be above the total entropy curve at the dew-point temperature, and below it at the air temperature.

In regards to the temperature to which the air should be refrigerated some consideration is necessary. In Fig. 2 is given a curve showing the quantity of vapor present in 75 lb. of saturated air at various temperatures. From this it is evident that the reduction in the weight of vapor for each degree the temperature is lowered is very slow after 25 deg. F. is passed, and even at 32 deg. F. is not rapid. At the same time the horsepower curves show that the power requirements increase rapidly for very slight reductions of temperature, and it is evident that the ratio of expenditure to gain is increasing so enormously that the balance point is soon passed.

This is shown by Fig. 6, in which is plotted the ratio of water removed from 75 lb. air to the power required for its removal below 40 deg. F.

This is based on 70 deg. F. condenser-temperature and single-stage non-regenerative refrigeration.

The saving in fuel in the furnace is directly proportional to the water removed, and the cost of plant and its operation nearly proportional to the power required, so it will readily be seen from Fig. 6 that a limit must soon be reached from the commercial point of view.

In summer all the uniformity possible would be reached by refrigerating to 32 deg. F., and all trouble from ice formation would be avoided by not going below this point.

As the weather became colder and the dew-point fell so as to be sometimes below this point, the diminished refrigeration required, and the lower temperature of cooling water available, would enable the same plant to maintain a lower temperature and still retain the uniformity desired by reducing the temperature of the air below the lowest natural dew-point probable.

This change being entirely under control of the manager would lead to no sudden changes, and would give a coke consumption in summer so nearly the same as that in winter that the difference would probably be inappreciable.

As between a refrigeration temperature of 32 deg. F. and one of 22 deg. F., with a blast temperature of 1000 deg. F. and normal coke practice, the saving for the latter would be about 2 per cent.

Using this chart as an implement of investigation we may now proceed to examine various methods of refrigeration.

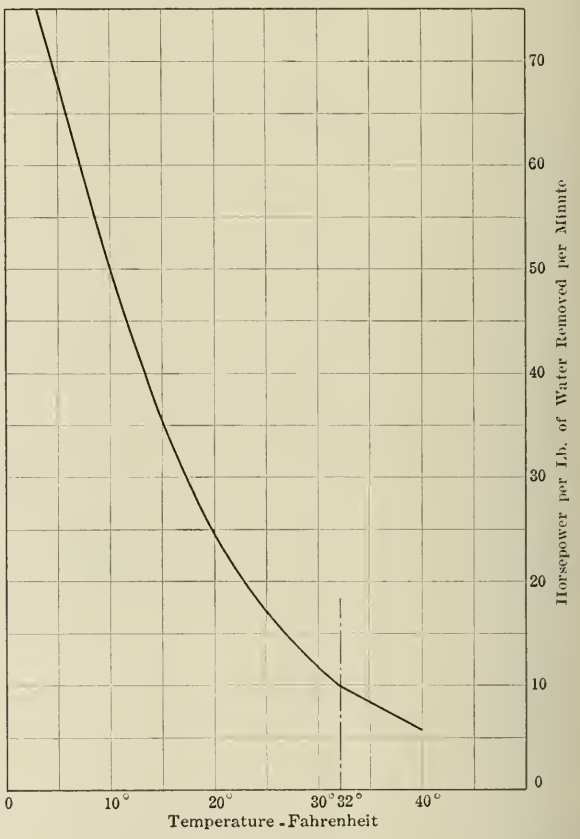


FIG. 6—HORSE-POWER REQUIRED PER POUND OF WATER REMOVED PER MINUTE IN REFRIGERATING BLAST TO TEMPERATURE BELOW 40 DEG. FAHR.—(DIRECT EXPANSION, SINGLE-STAGE, NON-REGENERATIVE REFRIGERATOR, CONDENSER TEMPERATURE 70 DEG. FAHR.)

In order to represent these methods graphically, and at the same time avoid marring the diagram, Fig. 5, for independent use, it is reproduced in Fig. 7 with the rectangles representing the cases to be discussed drawn upon it.

In order to facilitate comparison and reference certain data corresponding to frequent summer conditions, namely, a temperature of 85 deg. F., and a dew-point of 70 deg. F., a condenser-temperature of 85 deg. F., and that the air is to be refrigerated down to 25 deg. F., may be assumed.

Let us also draw for convenience on Fig. 5 the line of 10 deg. F. temperature-difference parallel to the curve of total entropy (VII).

The conditions assumed are then represented on the diagram by the figure *JadH*.

The rectangle drawn for these conditions is *ZJHG*, and its area is $5.60 \times 1.89 = 11.56$ sq. in., corresponding to 11.56 hp for drying 75 lb. of air between the limits and under the conditions assumed.

It is evident that the area below the curve of total entropy and the line of maximum entropy, above the line of minimum entropy, and to the left of the line of condenser-temperature, represents the theoretical minimum work for the performance of that amount of refrigeration. This must be increased in practice by moving the curve of total entropy 10 deg. F. to the left to give the necessary temperature-head. This is the curve of 10 deg. F. temperature-difference on Fig. 7, and is approximately a diagonal line across the diagram, making the area roughly triangular. On the other hand, the energy-diagram of the ammonia refrigerating cycle

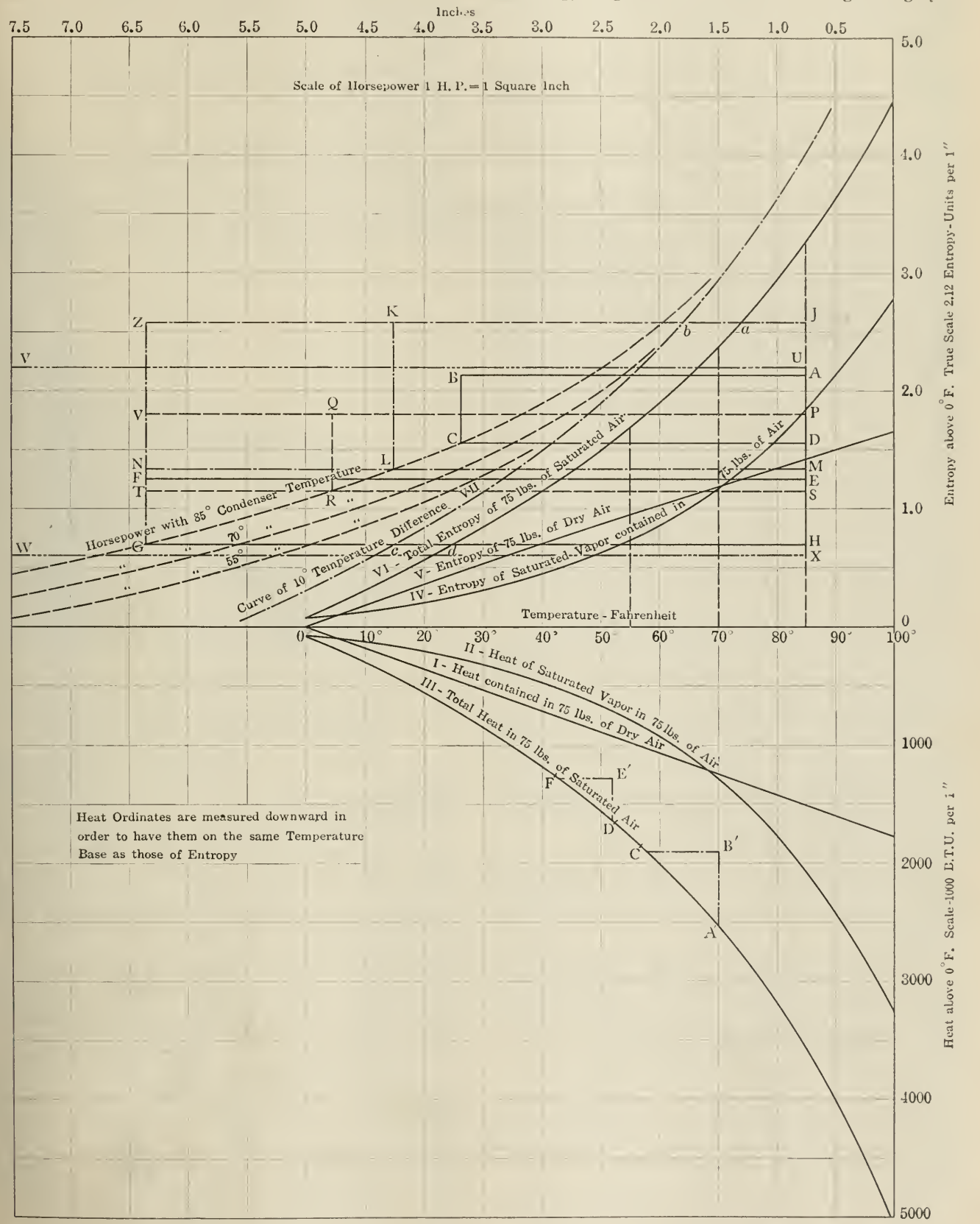


FIG. 7—TOTAL HEAT TEMPERATURE ENTROPY DIAGRAM APPLIED TO DETERMINING POWER FOR DIFFERENT METHODS OF BLAST REFRIGERATION

is, as already stated, a rectangle, and as it must be as large in every direction as the diagram of energy required, it is obvious that there must be a large quantity of waste room in the former diagram and that, accordingly, energy is being wasted.

This is also evident from an inspection of Fig. 2 since this shows that of all the moisture contained in the air at 70 deg. F. half is precipitated when the temperature is lowered to 50 deg. F., and of that removable down to 25 deg. F. almost two-thirds, yet the heat of all this is removed at the temperature of 25 deg. F.

This is precisely as if, in pumping from a shaft 45 feet deep, in which three-fifths of the water entered in the upper 20 feet, we put one pump at the bottom and let all the water run down to that level before pumping it out. It is really much worse than this, because in pumping heat the power required increases much faster than the head, while with water this is not so.

The remedy is as obvious in refrigeration as it is in pumping, to have two pumps, catch the greater part of the heat near the top of its scale and pump it out from there, pumping from the lower level only the heat which comes in at or near that level, a much smaller quantity.

This means the use of two ammonia compressor-cylinders, one working from the 15 deg. F. suction-temperature as before, the other working from a much higher suction-temperature, say 36 deg. F., both, of course, working to the same condenser-temperature.

The rectangle for the latter of these extends from the line of maximum entropy for the case assumed, *JK* in Fig. 7, down to the line *IM* through 46 deg. F., on the "total entropy curve," the end lines being drawn as before, the whole rectangle being *JKLM*.

The rectangle for the first-mentioned cylinder extends from the line *NLM* down to that of minimum entropy *GH*, the completed rectangle being *MNGH*.

The area of the first of these is $3.50 \times 1.25 = 4.375$ square inches; of the latter $5.60 \times 0.64 = 3.575$ square inches; total 7.95 square inches, corresponding to 7.95 horse-power per 75 lb. of air, as compared with 11.56 horse-power for doing the same work in one stage.

This involves also the great advantage that most of the water is removed at a temperature above freezing, so that the quantity of ice which can form is greatly reduced, even in the coils of the second stage.

Three stages could similarly be used, but with a much smaller saving, as an inspection of the area outside the "85 deg. horse-power curve" will show, so that the added complication of another stage would probably be a poor investment, especially as other considerations, to be mentioned presently, contribute to reduce the relative economy and desirability of this step.

The air leaving the refrigerator chamber is at the temperature of 25 deg. F., and it is plain on the briefest consideration that this may be used for cooling the incoming air, with a saving of power to the refrigerating machine.

What the amount of this cooling will be is, of course, not a question of entropy, but simply one of heat. It is not, however, one of easy algebraic solution, since the total heat of the vapor is a very complicated function of the temperature, that of the air being, of course, a perfectly simple one of direct proportion.

It is for this purpose that the curves of heat are added below those of entropy on the diagram.

The problem is: Given 75 lb. of dry* air at 25 deg. F., allowing a temperature-difference of 10 deg. F., and using the counter-current system of cooling, to what temperature will 75 lb. of air at 85 deg., saturated with vapor at 70 deg. F., be cooled?

Neglecting the insignificant superheat of the vapor, the air must be cooled from 85 deg. F. to 70 deg. F. before the moisture will be a factor, and the specific heat of air being constant this will obviously warm the dry air up from 25 deg. F. to 40 deg. F.

As 10 deg. F. difference of temperature to give the necessary thermal head is assumed, the dry air will be discharged at 75 deg. F., and the heat absorbed by it, from 40 deg. F. to 75 deg. F., is obviously that available for cooling the saturated air below 70 deg. F.

Taking from the curve "heat of dry air" that due to 35 deg. F. difference of temperature, we measure it off (towards the axis) from the 70 deg. F. point on the curve of total heat; it comes to 1992 British thermal units, the line through which intersects the total heat curve at 58 deg. F.

This transaction is shown by the lines $A^1B^1C^1$ in Fig. 7. From this it is obvious that the line of maximum entropy for this case is that through the temperature 58 deg. F., which is simply transferred vertically over to the total entropy curve. This line is shown at *VP* in Fig. 7, the whole rectangle being *VPHG*, whose area

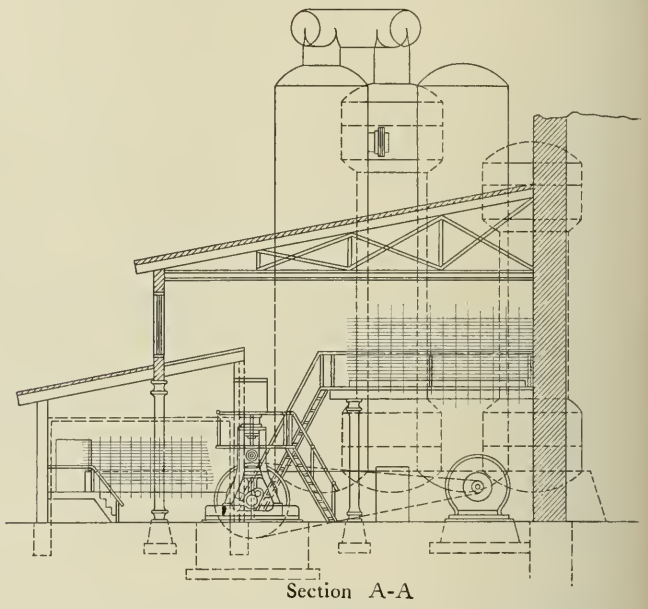


FIG. 8—ELEVATION OF CARRIER DRY-BLAST PLANT—(AMMONIA COMPRESSORS, MOTOR DRIVEN)

is 1.11 x 5.6 = 6.22 square inches = 6.22 horse-power, as compared with 11.56 horse-power for the same work without regeneration.

With this improvement can now be combined that of stage refrigeration, by which is obtained the two rectangles *PQRS* and *TSHG*, whose areas are 3.72 x 0.66 = 2.45 square inches, and 5.6 x 0.45 = 2.52 square inches, corresponding to a total of 4.97 horse-power per 75 lb. air when refrigerated in stages and with the aid of regeneration.

From this it will be seen that great economies are effected by the use of the direct expansion system, by refrigerating in two stages and by regenerating the "cold" in the air which has passed through the system, for the purpose of cooling down the incoming air.

There is also another possibility in the direction of economy which received consideration in the original development of this process by Mr. Gayley and was brought out in the discussion of my paper, that is, the utilization of the reduction of the volume of the air due to its being compressed for delivery to the furnace. If the blast pressure is fifteen pounds obviously the volume of the blast at atmospheric temperature is reduced to fifty per cent of its original amount, and obviously also since the quantity of vapor present per cu.

*The trivial amount of water vapor still present is neglected, being only 0.4 per cent. of the total weight.

ft. is a function of temperature only, this means that if the air were saturated before compression half the moisture would be squeezed out of it by compression, if its temperature were reduced to that of the atmosphere after leaving the blowing engine. This means plainly two things. First, less moisture to be condensed; second, the moisture present will be condensed to any desired limit with a higher dew point. This also means a saving in power.

In the early plants where the air was cooled by the introduction of vast masses of pipe coils into its path it was virtually impossible to have chambers which would withstand the blast pressure necessary, and of a size to contain this mass of coils without prohibitive expense and perhaps danger, therefore in these the refrigeration is always done before the air enters the blowing engine, but in later years the system of cooling the air by direct contact with a "rain" cooled by the refrigerating coils has been introduced and this eliminates the necessity for pipe coils in the refrigerating chambers, thus reducing the latter to relatively small dimensions, and this makes possible the use of the "post-compression" system of refrigeration.

This system has been worked out and applied by the

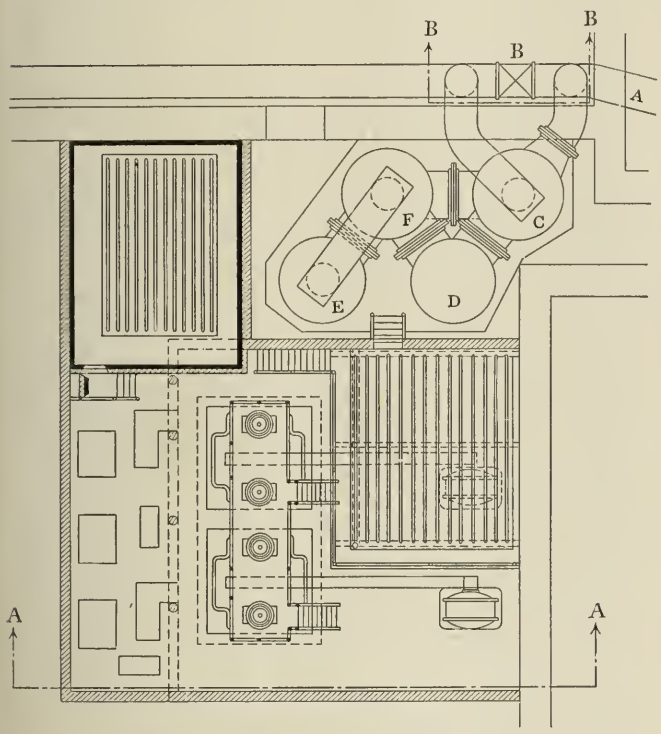


FIG. 9—PLAN OF CARRIER DRY BLAST

Carrier Air Conditioning Company of America, who also use regeneration and refrigeration in stages. A plant designed by them is shown by Figs. 8, 9 and 10. Fig. 8 shows a side elevation of the ammonia compressor (motor driven), and the ammonia condenser, also of the brine coolers, while behind, rising above the shed roof of the compressor house, are shown the outlines of the cooling chambers. Fig. 9 shows a plan of the same equipment. *C*, *D*, *E* and *F* are the various cooling chambers which can best be described by reference to Fig. 10, but before passing to this it is well to note that the cooling chambers are so arranged in reference to the blast main *A* that the blast can be thrown through them by closing the intermediate valve, or by closing the cut-off valves in the connecting necks and opening the intermediate valves, the cooling chambers can be cut off and the blast can go to the stoves direct, thus giving an opportunity to throw the refrigerating plant out of service without shutting down the furnace.

Fig. 10 shows the coolers *C*, *D*, *E*, *F* as if they were arranged in a straight line so as to show the currents through them. *C* is a heat exchanger in which the cold outgoing air is warmed up almost to inlet temperature by the warm incoming air from the blowing engine. This accomplishes two good results. It sends the air warm to the stoves, and, much more important, it does a part of the cooling which would have otherwise to be done by more expensive means, i.e., direct refrigeration.

From *C* the blast passes into *D*, which is simply a spray tower supplied with natural cold water. This continues the refrigeration begun in *C*, and remembering that cooling water is generally available at or below the dew point of the air, and that the density of the air is approximately doubled by compression before entering this system, it is obvious that the temperature produced by such natural cooling water will precipitate much of the moisture. From D the air passes into the base of *E*, which like *C* is a heat exchanger. The cold air coming from the second spray tower presently to be described, and at the lowest temperature reached in the system, enters at the top of *E* as shown, while the incoming air to be refrigerated enters at the bottom, and passing in counter-current through the tubes of the exchanger is cooled to an important extent, while the outgoing blast is, so to speak, prewarmed for its entrance into *C*, because of course it is by-

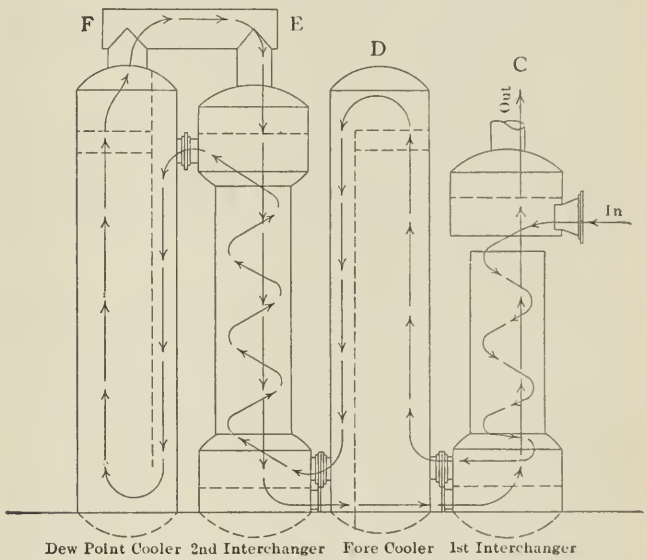


FIG. 10—DIAGRAM SHOWING ARRANGEMENT OF COOLING TOWERS AND REGENERATORS IN PROPER RELATION

passed around *D* and passes directly from *E* to *C*. From *E* the ingoing air enters the second spray tower *F* cooled with water refrigerated to a temperature between 32 and 40 deg. F. These spray towers have two great advantages. First, they avoid the use of expensive tubes for heat transmission. Second, they obtain immediate and practically unlimited contact with the air to be cooled so that the drop in temperature between the two is practically negligible. The incoming air therefore is reduced virtually to the temperature of the cold rain, or somewhere about 38 deg. F. From Fig. 5 it will be seen that at this temperature the moisture is .38 lb. per cubic foot; from this, remembering the compression of the air under which these conditions prevail, we find .19 lb. per cubic foot as the equivalent moisture in uncompressed air. This corresponds to a dew point of 22 deg., and is as low as it is economical to go in blast refrigeration.

One point of much importance is to be noted here. The temperature of the cold rain is well above the freezing point, while to secure a corresponding degree of refrigeration on the precompression system it is necessary to refrigerate well below the dew point, and this introduces all the complications caused by ice.

Both the pre-compression and post-compression systems have their advantages and their disadvantages. One of the principal merits claimed for the dry blast in its early days was that it produced a uniformity in conditions, in the quantity of air and the oxygen contained therein, delivered to the furnace per minute, and a considerable number of metallurgists attributed entirely to this fact the improvement in the operation of the furnace which it brought about. To the latter view I have never been able to subscribe. I shall later show what seemed to me conclusive reasons for believing that the great advantage of the dry blast lies in its dryness. At the same time the advantages of uniformity are not for a moment to be ignored. Now it is obvious that if the blast be reduced to a constant temperature, say to 25 deg. F., which was the practice at one time, nearly all the moisture as shown by Fig. 5 is removed from it, and the quantity remaining is made perfectly uniform while the temperature and therefore the density of the air are likewise rendered uniform. It then becomes necessary only to run the blowing engine at a constant speed to secure all the advantages of a constant weight of air per minute to the furnace. If a constant quantity of air be blown it is obvious that its volume after compression must vary from hour to hour and day to day on account of the varying pressure required by the blast furnace which produces a corresponding variation in the density of the air. Therefore if the quantity of moisture per cubic foot be kept the same by having an absolutely uniform temperature after refrigeration, the variation in the number of cubic feet due to the cause just explained still causes some variation in the actual quantity of moisture delivered to the furnace.

In recent years it has become the practice to change the speed of the blowing engine according to changes in the temperature of the inlet air to compensate for the corresponding variations in its absolute volume. So far no one has as yet introduced a compensation for variations in barometric pressure, though doubtless that refinement will come at some plants in time.

No difficulty is found in keeping constant the weight of air delivered to the furnace by this simple means. The Carrier Air Conditioning Company have applied the same idea to securing a constant quantity of moisture in the blast irrespective of the blast pressure, regulating the dew point by means of changes in the temperatures of the refrigerating apparatus; they have also developed a mechanism whereby this change is automatically made, thus securing a constant weight of moisture with varying blast pressure.

Another respect in which the pre-compression and the post-compression system differ is that with the former all the air is delivered to the blowing engine cold, and the reduction in volume resulting from this causes proportional reduction of the power required by the main blowing engine. On the other hand the refrigeration expended upon the air at a considerable expense, is lost except for this saving. Now it can easily be proven by thermo-dynamics that if both the refrigerating machine and the blowing engine were perfect the total power required to refrigerate the air down to any desired temperature, and then compress it from that low temperature, would be exactly the same as the power required to compress it directly from atmospheric temperature. It becomes therefore a question as to which machine is the most efficient, a question easy to decide, for we know that good blowing engines are from 85 to 90 per cent efficient, while even good refrigerating plants are only around 55 per cent. It is obvious, therefore, that it pays to save power in the refrigerating machine even at the expense of the blowing engine. But another point is to be considered here. When the pre-compression system is used the blast containing much of the heat of compression passes at once to the stoves and of course reduces the amount of heat to be imparted by the stoves proportionately, whereas the post-compression system if applied the same as the original pre-compression systems would deliver strongly refrigerated air to the stoves with corresponding increase in the heat required of them.

It is partly to overcome this disadvantage that the Carrier Company uses the first exchanger shown in their system since by the aid of this they can warm up the outgoing air within a few degrees of the temperature of the incoming air. This puts matters on practically an even basis as regards the heat to be supplied by the stoves.

Using the post-compression system permits giving paramount consideration to the power requirements, and these, as has been pointed out, are greatly reduced by the use of exchangers and the two-stage system. They are also further reduced by the fact that the temperature to which the air must be refrigerated is not nearly so low as under the pre-compression system to reduce the moisture to the same number of pounds per minute. This has a very decided bearing on the power requirements, since it has been shown (see article in *Metallurgical and Chemical Engineering*, December, 1912, above mentioned) that the power required for any given quantity of refrigeration (Q) is

$$HP = 0.0235Q(Z + 3.7Z^2)$$

in which Z is equal to $\frac{T_1 - T_2}{T_1}$ and this is obviously less as the temperature to which we refrigerate is raised. Moreover, while the quantity of refrigeration for the condensation of the moisture is the same, that for the cooling of the air is less, because the temperature to which the given weight of air is cooled is not so low in the post-compression system as in the other, it is therefore obvious that the power required must be very materially less with this system than with pre-compression.

A considerable advantage in the use of exchangers inheres in the post-compression system for the reason that the greater density of the air greatly increases the ease with which heat may be imparted to or abstracted from it, and the exchangers can therefore be smaller on this system than they could for an equal degree of efficiency if used on the pre-compression system.

The slightly lowered temperature at which the air is delivered to the stoves constitutes the principal objection to this system when the blast furnace pressure is twelve pounds or more, but when the pressure is less than this the reduction in volume of the air is very much smaller, and the advantage of the system falls off proportionately, so that there may be cases in which it is desirable to use the pre-compression system, but in such cases there is no excuse for not using two-stage cooling and regeneration.

It may be thought that the cost of the regenerator is just that much addition to the total cost, but this is by no means the case. The regenerator does, without consuming any energy, a part of the refrigeration which would otherwise have to be done by the refrigerating machine, and therefore makes a proportionate reduction in the size of refrigerating equipment required, whose cost per unit of work done is of course very much greater than the cost of the regenerator.

By the use of the rain system two great advantages are obtained. First: The avoidance of the heavy cost for brine circulating coils and the chambers in which to enclose them. Second: The avoidance of the additional drop of temperature required to force the heat from the air into the brine through pipe walls which involves a lower temperature of refrigeration for a given degree of moisture removal. The whole plant is made smaller and more compact and in every way cheaper and better by this system.

If rain be used for carrying the heat from the refrigerating coils to the air, as is most desirable, it becomes necessary to use a non-freezing solution for this purpose if the second stage of the refrigeration takes the temperature below the freezing point as a pre-compression system should probably do. For this purpose brine, preferably made with calcium chloride, should be used, and as this obviously takes up most, if not all of the moisture from the air which it cools, an evaporator must be arranged at some point in the circuit to remove the accumulated water from the system and maintain the strength of the brine. In such a case a heat exchanger should be installed between the refrigerating system and the evaporator so that the "cold" in the incoming and the heat in the outgoing brine may both be conserved.

(*To be concluded in August issue*)

The Relative Migration Velocities of the Ions in Complex Electrolytes

BY A. MUTSCHELLER

In a former paper on "The Action of Certain Colloids on Ions During Electrolysis,"[1] the author has given experimental data which are in support of a theory explaining the function of certain colloids when added to a heavy-metal electrolyte for the purpose of obtaining a smooth and consistent metal deposit on the cathode. The discussion relates to the change of velocity of the ions which take part in the electrolysis, which change is brought about by the addition of a certain quantity of certain colloids to the electrolytic bath.

It is shown in that paper that certain reversible colloids, as for example, gelatine, gum arabic, soluble starch, etc., exert a neutralizing action on one of the ions, thereby rendering it unsusceptible to the force of the electric field across the bath so that the other ion is left alone active in the electrolyte. This formation of an electrically neutral complex is due to the so-called protective action of the colloid added and consists in the formation of absorption compounds, the colloid which carried an electric charge having combined with the ions of opposite charge, which are in this case the anions.

The removal of one ion by the oppositely charged colloid causes the ionization of the unionized part of the salt in solution to continue until the ionization constant is again satisfied. Under these conditions, therefore, the free ions, i.e., those left in the solution, are the sole ionic constituent of the electrolyte, hence the flow of electric current through the bath is effected through the transport of electricity from the anode to the cathode by the remaining cations in case the colloid was positively charged and was, by virtue of this charge, absorbed by the anions. This, then, it was found, is the condition of successful deposition of metals, for, as long as the concentration of the cations is being maintained constant around the cathode, no formation of trees or loose and brittle deposit is taking place.

Since it is well known that the charge carried by a particle of a colloid is not that of one electron but ordinarily an indeterminate multiple thereof, it is necessary to find by experiment the right amount of colloid, or rather the right amount of electric charge on the colloid, that must be added to the electrolyte in order to just balance the electric charge of the anions. It has been shown in the above mentioned paper that, if there is an excess of positively charged colloid, the absorption complex is positive and will migrate to the cathode and deposit there, i.e., the anions are actually carried to the cathode. If, however, on the contrary, there is a deficiency of positively charged colloid, the negative character of the charge of the anions will prevail and the complex of colloid and anions will migrate to the anode.

While the above-named paper was in preparation, the experimental part of the present communication was in progress. Moreover, the conclusions of the first paper could not be accepted as general principles if they did not apply to the case of the complex electrolytes which are used in practical work for the reason that they also give smooth and compact deposits.

Collections of the formulæ[2] of various solutions that have been proposed for the electrodeposition of the more common metals consist characteristically of complex solutions of cyanide or ammonia salts of the metal to be deposited or potassium cyanide or some ammonium salt is mixed with the electrolyte. A few "plating solutions" have been selected as typically representative of these classes, and in the following is given a discussion, together with the results of an experimental investigation, on the relative velocities of migration of the ions involved in the process.

The Silver-Cyanide Plating Solution

According to Bodländer[3] silver forms a series of complex ions with potassium cyanide, the composition of which depends on the relative quantity of cyanide present in the solution. The formation of the first salt takes place according to the following equation:

$AgNO_3 + 2KCN = KAg(CN)_2 + KNO_3$. The next salt which forms with a greater excess of cyanide is

$AgNO_3 + 3KCN = K_2Ag(CN)_3 + \ldots$ and so on for the higher salts. If these salts are submitted to electrolysis, using inert electrodes, it is found that the silver does not migrate to the cathode but instead goes to the anode, whence silver must be a component of the anion. This complex anion has been formed then by the combination of a positive silver cation with two negative cyanide anions which produce the monovalent negative argento-cyanide[4] ion $Ag(CN)^-_2$, or the divalent ion $Ag(CN)^=_3$, etc. These ions themselves, however, are not completely stable; they in turn dissociate, satisfying a certain equilibrium constant. Hence, for the dissociation or splitting up of these complex ions we have the relation

$$KAg(CN) \rightleftarrows K^+ + Ag(CN)^-_2.$$
$$KAg(CN) \rightleftarrows 2K^+ + Ag(CN)^=_3, \text{ etc.}$$

Moreover, as these complex ions are not absolutely stable, a further ionization takes place according to the following scheme

$$Ag(CN)^-_2 \rightleftarrows Ag^+ + 2CN^-.$$
$$Ag(CN)^=_3 \rightleftarrows Ag^+ + 3CN^-; \text{ and so on.}$$

Or $[Ag^+] \times [CN^-]^2 = [Ag(CN)^-_2] \times k_1$

$[Ag^+] \times [CN^-]^3 = [Ag(CN)^=_3] \times k_2$, etc.

Bodländer determined these constants and found k_1 equal to $8.8 \cdot 10^{-22}$ and k_2 to $1.13 \cdot 10^{-22}$.

The instability of these ions is probably considerably

[1] This journal, June, 1915.

[2] *Trans.* Am. Electrochem. Soc., vol. 23, 17-26 (1913). Watts, Lab. course of El. Chem. pp. 72-83.

[3] *Zeit. f. anorg. Chem.*, 39, 196 (1904).

[4] The acid $HAg(CN)_2$ is crystallizable and is found to be a strong acid. Its potassium salt $KAg(CN)_2$ is, therefore, also highly ionized. (Stiglitz, Qual. Anal.).

increased while the complex ion migrates to the anode. The residual positive charge of the silver ions bound in the complex ions enters more and more into the region of the repelling positive force of the anode while the attractive force on the negative cyanide ions due to the same electric force increases at the same rate. The cyanide anions, therefore, are attracted toward the anode whereas the silver cations are repelled toward the cathode. With the products of this ionization thus rapidly removed, even the very small degree of dissociation is sufficient to furnish a sufficiently abundant number of silver ions which are to be deposited. The cyanide anions, in case that a silver anode was used, forms the argento-cyanide[5] salt of silver ($Ag\,Ag(CN)_2$). This salt then immediately breaks up again as above outlined and the silver ions migrate to the cathode in order to be deposited there.

Again, there being potassium ions present from the first ionization, we must naturally expect them to appear at the cathode where the potassium formed acts on the water and forms the hydroxide and hydrogen gas. These products act on the complex cyanide salt present and thereby set silver ions free; thus

$$2K^+ + 2H_2O = 2KOH + 2H^+.$$

$$2KOH + 2H^+ + 2KAg(CN)_2 = 4KCN + 2H_2O + 2Ag^+.$$

$$2K^+ + 2KAg(CN)_2 = 4KCN + 2Ag^+.$$

It is to be observed at this point that potassium does not deposit, but only frees the silver ions, and those require for their own deposition new electrical energy, hence the equivalent of silver ions that originate at the anode are not deposited at the cathode and so we should expect an increase of silver at the cathode side of the bath. If, again, this increase actually occurs, this would be an equally sure indication that the dissociation of the complex salt does not take place throughout the bath but at the anode only and thus it would become evident that the cyanide ions do not at all take part in the migration or transport of electricity across the bath.

In order to fully investigate this question, the following series of experiments have been performed.

EXPERIMENTAL PART.

The formulæ generally recommended for the silver plating solution differ considerably in the quantity of free potassium cyanide that should be present in the solution. The solution used for the present purpose was prepared by precipitating silver nitrate with potassium cyanide and washing this precipitate by decantation. It was then redissolved by further addition of potassium cyanide solution employing care to make the excess very small. The excess was tested by adding $\frac{N}{10}$ silver nitrate solution to 10 cc. of the prepared solution. About 0,7 cc. were required to cause a permanent precipitate. The chemicals used were of c.p. quality.

This solution was introduced into the H-shaped migration tube described in the former paper and platinum was used as cathode but pure silver wire as anode. The silver in the original solution and the silver in the solution of the cathode compartment after various times of run was determined by electrolysis with a platinum dish as cathode and a heavy platinum foil as anode. The deposited silver was pure white after washing, drying and slight heating.

In table I the increase of silver in the cathode compartment is given for various amounts of silver deposited on the cathode in runs from ½ to 3 hours. The concentration of the electrolyte was 5 $KAg(CN)_2$ to 100 water, with a slight excess of KCN.

[5]Bodländer shows that silver forms ions of this type more readily and completely than $(AgCN)_2$. *Zeit. f. anorg. Ch.*, *39*, 196 (1904).

Table I

Experiment No.	Amount of Silver Deposited on Cathode	Silver Migrated Toward Cathode	Increase of Silver in Cathode Compartment
1	0.0147 gr.	0.0228 gr.	0.0082 gr.
2	0.0234 "	0.0363 "	0.0129 "
3	0.0652 "	0.0984 "	0.0332 "
4	0.0761 "	0.1152 "	0.0391 "

It follows, therefore, from the experimental determinations that there is actually an increase of silver found on the cathode side of the plating bath. The silver ions are the only carriers of electricity across the solution and the single anions (the CN^- ions) do not participate in the transportation of electricity such as they do in non-complex-ion electrolytes and in the absence of certain colloids such as described in the first publication.

The Nickel- and Zinc-Ammonia-Sulphate Plating Solution

The electrolytic baths generally recommended for the deposition of the metals nickel and zinc consist almost exclusively of an aqueous solution of a salt of the metal and an ammonium salt or the metal-ammonium double salt. In some cases other additions are made: for example, more ionized salts are added to decrease the resistance of the bath (such as $ZnCl_2$ to the zinc plating solution). Other additions such as sulphides, thiosulphates, hyposulphites, etc., are made for the purpose of influencing and changing the color of the deposit. Their functions are secondary and their presence has no bearing on the general form and quality of the deposit.

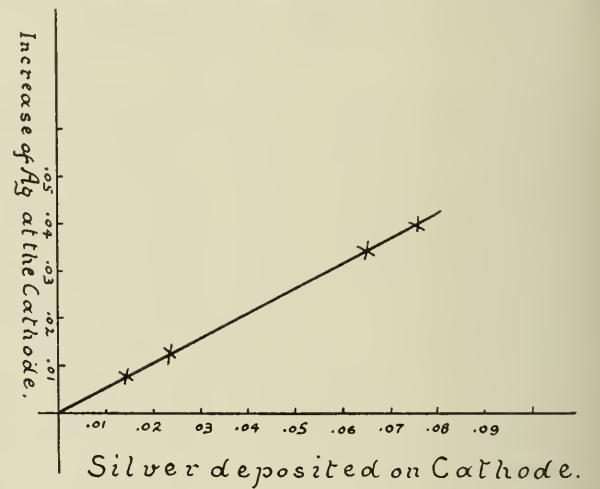


FIG. 1—SHOWING THE GRADUALLY INCREASING SILVER CONCENTRATION IN THE CATHODE COMPARTMENT

In view of the fact that all these metal ions enter into the formation of complex ions, it would appear that, if the relation of their ionic migration velocity should turn out to be approximately the same as that in the silver-cyanide salt, the same working principle would apply for the complex metal-ammonia ions. Assuming for an instant that all these conditions do hold, it must be remembered that cyanogen with silver forms a complex anion, whereas ammonia with metals forms complex cations. The mechanism of the working of these ions must, therefore, be different from that of the silver-cyanide ions.

When ammonia is gradually added to a solution of a zinc salt the following changes probably occur: In the first stage zinc hydroxide is precipitated

$$ZnSO_4 + 2NH_3 + 2H_2O = (NH_4)_2SO_4 + Zn(OH)_2 \quad (1)$$

The zinc hydroxide then dissolves in an excess of ammonia with the formation of a soluble base

[6]Abstr. *Chem. Zentralblatt*, *11*, 265 (1900).

$$Zn(OH)_2 + 2NH_3 = Zn(NH_3)_2(OH)_2 \quad (2)$$

the complex zinc-ammonia base probably reacts further with the ammonium sulphate

$$Zn(NH_3)_2(OH)_2 + (NH_3)_2SO_4 = Zn(NH_3)_4SO_4 + H_2O \quad (3)$$

The complex zinc-ammonia salt is probably electrolytically dissociated according to

$$Zn(NH_3)_4SO_4 \rightleftarrows Zn(NH_3)_4^{++} + SO_4^{=} \quad (4)$$

Konowaloff[6] determined the partial pressure of ammonia in ammoniacal salt solutions by drawing a current of air through the solutions contained in a thermostat at 60° C. into a standard acid solution. He finds that the partial pressure of the ammonia of the salt solutions is expressed by the formula

$P = P_1(n - km)$, . . where P_1 is the partial pressure of ammonia from pure aqueous ammonia solutions, n is the number of grammoles of ammonia and m the number of grammoles of salt per liter; k is a constant. For silver nitrate he finds $k = 2$; for zinc nitrate, nickel chloride, copper and cadmium nitrate, etc., k is approximately 4 (3.4 to 4.04). In the case of some other solutions which are not precipitated by ammonia and afterwards redissolved he found the partial pressure of ammonia in such ammoniacal solutions to be greater than in pure aqueous ammonia solutions (except in the case of calcium and strontium chloride). Hence, the compounds existing between the salt and ammonia are of the type $M(NH_3)_nX_2$, or for nickel and zinc $Ni(NH_3)_4SO_4$ and $Zn(NH_3)_4SO_4$.

Dawson and McCrae[7] applied the law of distribution (Nernst), according to which the condition of equilibrium at a given temperature is determined by a constant ratio of the concentrations in the two immiscible solvents, if the molecular weight of the distributed substance is the same in the two media. In other words, this constant or coëfficient of partition of a substance between two solution media indicates any change which took place in the molecular configuration when the substance entered the other medium. (Hantsch and Sebaldt.[8]) The deviation of the distribution coëfficient for the salt solution from the value found for pure water and a non-miscible medium will measure the complexity of the compound. As such molecular changes probably occur in some ammoniacal salt solutions, the investigation of the distribution coëfficient of ammonia between such salt solutions and a medium non-miscible with water will indicate the formation of any complex compounds produced by the combination of the salt and ammonia.

The results of these investigations indicate that in a certain number of solutions investigated in presence of a considerable excess of ammonia one molecule of the salt takes up four molecules of ammonia, and that this ammonia can no longer act as free ammonia and enter into the establishment of the equilibrium between the aqueous medium and chloroform. The ratio obtained suggests the existence of compounds of the formulæ

$Cu(NH_3)_4SO_4$, $Ni(NH_3)_4SO_4$, $Zn(NH_3)_4SO_4$, etc.

If we now assume that these salts ionize according to the scheme

$$Cu(NH_3)_4SO_4 \rightleftarrows Cu(NH_3)_4^{++} + SO_4^{=}$$
$$Ni(NH_3)_4SO_4 \rightleftarrows Ni(NH_3)_4^{++} + SO_4^{=}$$
$$Zn(NH_3)_4SO_4 \rightleftarrows Zn(NH_3)_4^{++} + SO_4^{=}$$

we should expect that the addition of sodium sulphate would have an influence on the equilibrium between the copper salt and ammonia. This, however, is not the case, for experiment shows that the addition of sodium sulphate has no influence on the equilibrium, the proportion of combined ammonia remaining the same.

[7] *J. Chem. Soc.* 77, 1239, (1900).
[8] *Zeit. phys. Chem.* 30, 258, (1899).
[9] *Ber. d. chem. Ges.*, 36, 3403, (1903).

The further dissociation of the resulting complex ions has also been investigated and it was found that they also ionize according to the scheme

$$Ni(NH_3)_4^{++} \rightleftarrows Ni^{++} + 4NH_3^{\circ},$$
$$Zn(NH_3)_4^{++} \rightleftarrows Zn^{++} + 4NH_3^{\circ}, \text{ etc.}$$

Euler[9] determined the constant of dissociation for the zinc-ammonia ion

$$[Zn^{++}]\,[NH_3^{\circ}]^4 = [Zn(NH_3)_4^{++}] \times 2{,}6 \cdot 10^{-10}.$$

Ammonia originating from this dissociation is not an ion, but ammonia in the elementary state. As such it diffuses rapidly into the solution and as the investigations of Konowaloff and Dawson and McCrae show, it forms the complex ammonia-metal ions with the zinc or nickel salt in the solution.

Leaving for the present the question undecided, whether the Cu^{++}, Zn^{++}, or Ni^{++} exist as single or complex ammonia ions in the solutions which are recommended as electrolytes, there can be no doubt that the metal ions and the ammonium ion together migrate to the cathode. That ammonium, after being liberated, forms ammonia, and as such interreacts with the metal ions present to form the complex ions follows from the above mentioned investigations. Hence, this case is of the same mechanism as the silver-cyanide equilibrium. That is, the complex ammonia ion forms an intermediate product which dissociates in turn, forming with the anions a salt by means of which the anions are withdrawn from the function of transporting electricity from one electrode to the other.

From this hypothesis it must again be concluded that the cations alone transport electricity, so that the full equivalent of metal that is deposited must migrate toward the cathode. If, then, the ratio between the metal and the ammonium salt are properly balanced, there should be no decrease of concentration of the metal ions in the fluid of the cathode compartment during the run.

This investigation was carried out and the results together with a description of the methods of procedure are given in the following:

EXPERIMENTAL PART.

The determination of the relative migration velocities of the ions of the zinc and nickel plating solutions was carried out in the manner already described. The anodes were sheets of zinc and nickel respectively, and the quantitative determinations of the metals in the solutions were made by electrolytic analysis, using platinum as anode and a platinum dish as cathode. The solutions used were of the following composition:

The nickel plating solution contained $Ni(NH_3)_2(SO_4)_2$, 46 grams per liter of solution, and 5 drops H_2SO_4.

The zinc plating solution had the following composition: $ZnSO_4$ — 50 gr, $(NH_4)_2SO_4$ — 10 gr, $ZnCl_2$ — 2.5 gr, water — — 250 cc. The migration ratios were found such as given in the following tables:

TABLE II

Experiment No.	Amount of Nickel Deposited on Cathode	Nickel Migrated Toward Cathode	Decrease of Nickel in Cathode Compartment
5	0.0966 gr.	0.0870 gr.	0.0096 gr.

TABLE III

Experiment No.	Amount of Zinc Deposited on Cathode	Zinc Migrated Toward Cathode	Decrease of Zinc in Cathode Compartment
6	0.1507 gr.	0.1496 gr.	0.0011 gr.

As will be seen from these tables, there is a slight decrease of the concentration of the metal ions in the

cathode compartment. It is to be recalled, however, that the electrolysis starts with a liberation of ammonium at the cathode. At the anode we must naturally have the corresponding equivalent of sulphate ions appear. Probably the liberation of ammonium and subsequent formation of ammonia causes the formation of the complex ammonia-metal ion, hence, while the first complex ions are being formed at the cathode, there are some anions migrating and this then reduces the migration velocity of the cations to a value slightly less than one. Moreover, in the case of the argento-cyanide electrolyte the case is just reversed, for there the complex ions are already formed, but as the potassium salt which later changes into the silver salt. In case of a complex anion, there is a slight increase of metal in the cathode compartment, but in case of complex cations there is a slight loss and this fact is brought out by the results given in the tables.

Conclusion

Although Faraday's law is sometimes stated in the form that if a certain quantity of electricity passes across the solution of an electrolyte, there will be deposited the corresponding electrochemical equivalent of metal on the cathode, this statement of it is inadequate and does not include that the principle can be employed technically with success without further provisions as a process for the deposition of metal upon objects by simply making them the cathode in the electrolytic bath. The technical man says that in most cases the deposit does "not stick"; in other words, the metal deposit lacks certain qualities such as smoothness, purity, and consistency, which are indispensable for the successful technical utilization of the electrodeposition of metals.

In a former paper[10] the writer of this article has reported experiments which show that the addition of certain colloids, at the same rate as it improves the qualities of the deposit, influences the ionic migration velocities of the ions. The relative velocity of the cations is increased nearly to unity and that of the anions is decreased nearly to zero, while the quality of the deposit improves.

In the present paper an attempt is made to demonstrate that the same principle applies to the formulæ which are used as electrolytes for the deposition of the more common metals. There is agreement of the results, since all the solutions investigated, which give more or less smooth deposits on the cathode, have the relative velocity of migration of the ions altered in the way that the velocity of migration of the cations comes nearly to unity and the anions cease to take part in the migration so that their velocity is lowered to near zero velocity.

It appears, therefore, justifiable to state that the condition under which good deposits of metals are obtained is that the concentration of the metal ions at the cathode must remain constant during the deposition. This condition can only be obtained by excluding all ions ordinarily migrating toward the anode from the function of transporting electricity, so that the cations must migrate toward the cathode as fast as they deposit there. We have observed that if this condition is fulfilled there will be obtained the optimum of quality of the deposit.

Finally, it has been shown that this effect on the migration velocity of the ions can be exerted (1) by making the proper addition of positively charged colloid to the electrolyte, whereby the anions are absorbed and electrically neutralized, hence cease to migrate, or (2) either by composing the electrolyte of such complex ions whose products of dissociation re-engage the anions into a non-ionized or little ionized salt, leaving only the cations intact; or by using additions of such salts, which, as the electrolysis proceeds, form complex ions, the products of dissociation of which combine into non-ionized or little ionized salts with the anions, thus leaving the cations free and intact.

Chemical Laboratory, Pathological Department,
German Hospital and Dispensary,
New York.

[10] *loc. cit.*

Good Advice to Consulting Metallurgists and Others

In a paper published by Mr. W. B. Blythe in the *Proceedings* of the Australasian Institute of Mining Engineers, the author closes with some counsel to consulting metallurgists which is particularly appropriate for young engineers, and perhaps some older ones. We quote the following:

When everyting is running well and smoothly, and good profits are being made, there is no cause for worry; but with the turn of the tide of prosperity a reverse current generates doubt and uneasiness, and, among other things, a metallurgical examination is demanded. There is no finer test for genuine metallurgical ability and common-sense than these plant investigations. The operation calls for the exercise of skill, tact, diplomacy, patience, and analytical reasoning of the highest order over an extended period.

There is a tremendous inducement to rush in "where angels fear to tread" and condemn everything offhand as being antiquated, and insist on modernizing the whole scheme of operations. This inclination must be held firmly in check. Always remember that the man you superseded had brains, and that his length of service on the mine (if no other reason) renders his advice and recommendations of value. You will probably see anomalies staring you in the face at every corner. After you have been on the mine for some weeks you will find that most of them are not anomalies, but are real necessities under the existing circumstances. Never run down that predecessor of yours; the inclination to do so is strong at the beginning, but your respect for him increases later on.

When you make changes in the circuit of an old plant of an experimental nature, always, wherever possible, leave a loop-hole to get back to the old circuit. A sudden change usually upsets the equilibrium at some unforseen point, and unless precautions are taken a heavy loss will occur before these subordinate factors are straightened out. Start your investigations at the residue end of the plant—this is the most important, as an indicator of efficiency or otherwise; work back gradually to the mill; and do not hurry. Start by checking the results being obtained at the time of your arrival, and accept these as the basis of your recommendations. Do not accept for granted any previous figures as to extraction or tonnage.

Get your assays prepared by your assistant, and assayed by an independent operator. If they do not agree with the mine results, look for the reason. You will probably find that the error has crept in during the preparation of the samples for assay. Anyone can obtain a reliable result from a powdered sample, but it requires careful and conscientious labor to ensure that that ground sample is strictly representative of the original large bulk sample. The assayer is usually a conscientious, trained worker, who, under the stress of heavy routine duties, has not the time to superintend thoroughly the preparation of his samples—often this work is outside his province.

Keep all your assay results, and ideas generally, to yourself for the first week or two, and encourage the foreman to talk and advise you what to do. They probably all know more than you do at this stage, and they think more of you if you listen to them than if you adopt a bombastic attitude and start to lay down the law. Gradually introduce a few small improvements—if possible, some that the plant men have suggested first. They will work with you heart and soul to make these a success, and the personal element is an important factor in metallurgical operations. Clean the plant up, and the men will take a pride in keeping it clean, and in their work generally.

An eminent mining engineer once went to West Africa to report on some properties, and instead of starting in his report to discuss rises and winzes and the usual profit-making consideration, he launched off on to a technical dissertation on the mosquito. Well, the mosquito is a big factor in West African finance; so also are filthy conditions and general untidiness in the ordinary plant work. Dirty plants and low residues do not co-exist, but, unfortunately, the reverse does not always apply.

Improving plant conditions is a slow and tedious operation, but it must not be rushed. The investigator usually meets with silent and carefully veiled antagonism, and this must be overcome. The easiest way to overcome it is to improve the workmen's conditions, and these begin to improve from the commencement of the general plant clean-up.

The penny-wise-pound-foolish type of manager cuts down the number of hands until no cleaning or repair work is done at all. Temporarily reduced labor costs follow, but not for long; the increased losses and breakages resulting from this policy soon overshadow the saving in this direction.

Give the leading plant men, to a certain extent, your confidence, and show them the results of their work. There is no gain in the profound secrecy policy of some managements. It reminds one rather of the dark chamber of the alchemist and its veiled mysteries. Thrust on the leading men's shoulders a little responsibility; it pleases them and relieves your own, and they take an increased interest in their work.

Do not do any manual labor yourself, and remember that each man around the works can do his own particular duties a little better than you can, although at times you do not think so. When they seem slow, remember that they are not paid so much as you are. You are paid for your brains, and if you want to use them to the greatest advantage for your company you must not get physically tired. Always make out that things are quite as bad as they really are, and if you can improve them you will get due kudos. But if you are enable to realize your original reported anticipation you will meet with scant consideration. Never boast of your knowledge or achievements, as, excepting perhaps golf, the writer knows of no scientific pursuit where the boaster is so liable to be "hoisted with his own petard" as the searcher after the truth in the fields of metallurgy.

Lead Poisoning in Manufacture of Storage Batteries is the subject of Bulletin 16S of the Bureau of Labor Statistics of the Department of Labor. The author is Dr. Alice Hamilton. It is thought that the dangers of the industry can be reduced to a minimum by installing hoods and exhausts to carry off fumes and dusts by substituting machine for hood work, by providing ample washing facilities for the workmen and insisting on strict cleanliness everywhere and by providing a separate lunch room as the only place where food may be kept and eaten.

Metallurgical and Chemical Engineering in Great Britain

(From our London correspondent.)

Recent Progress in Pyrometry

Mr. C. R. Darling's paper with this title, read before the Royal Society of Arts on May 12—Sir Robert Hadfield presiding—almost synchronized with the Iron and Steel Institute meetings. It was both useful and interesting—particularly so with reference to the "ageing" of the thermo-couples of thermo-electric pyrometers, and to the protecting sheaths necessary to shield junctions from the corrosive action of furnace gases. Alundum, silfrax and silit were dismissed as not wholly suitable, the two first named owing to their being permeable to gases at high temperatures, and all three because of brittleness. A new type of sheath for use with molten brass or bronze, possessing a tip of molybdenum connected to a nickel tube covered with a protecting material was mentioned as being said to be satisfactory.

The use of resistance pyrometers at high temperatures was remarked as depending upon a protecting sheath capable of withstanding temperatures of 1400 deg. C. and over. Given the requisite material the author indicated that alundum would form a suitable resistance material.

Radial and optical pyrometers were explained and an excellent exhibition of typical pyrometers attracted attention at the end of the meeting. Before this, however, the discussion on the paper, opened by the chairman, was concerned with the importance of accurate measurements of temperature, and the citation of instances of the great changes in physical properties occasioned by small temperature differences. Sir Robert expressed his own preference for platinum and platinum-rhodium couples.

Dr. Harker of the National Physical Laboratory and Mr. H. C. Jenkins also spoke.

The Scottish Kelp Industry

A leaflet issued by the Board of Agriculture for Scotland says the kelp industry has improved in the last five years, and it would pay crofters and others in districts where the right kind of seaweed is found on the shore. Up to about seventy years ago kelp was made for the soda which was obtained from it. Other and cheaper ways of getting soda were found out, and the price of kelp became lower and lower, so that in many districts the people gave up the making of it. Soon afterward iodine and potassium began to be extracted from kelp and the price rose slightly. There were ups and downs but on the whole the value increased. From 1907 to the early part of 1914 this rise in value became marked.

Potash has been obtained almost entirely from Germany where there are mines of it. Consequently, as long as the war lasts, the only important available source of potash will be kelp and hence the price of kelp has increased since the war. The consumption of potash is very great. It is the main constituent of several important artificial manures, besides being largely used in manufactures. Also, since iodine is in growing demand in military surgery, its value, too, is likely to become higher; though even during the war the increase is not likely to be so great as in the case of potash because iodine is obtained from the nitrate fields in Chile as well as from kelp.

Just before the war it may be estimated that the price which the workers might except to receive for 1 ton of kelp was £5 to £5 10s. It is probable that this season at least £1 more per ton may be obtained. To secure this sum the worker will have to gather the proper weed, to dry it and then burn it. It requires about 5 tons of dry weed to make 1 ton of kelp.

International Commerce

There will be some startling national trade balance sheets when once the war ends. One does not only refer to casualty lists, national indebtedness or property destroyed. There is, too, the cost of the industrial dislocation inseparable from the diversion of labor from the loom to the trench and the exchange of the plough for the machine gun. Some indication of this is given in some recently published statistics of the external trade of France. In these imports and exports for the first five months of the war are compared with the imports and exports for the similar months in the preceding year. The net result is that imports fell to 59.5 per cent and exports to 66.5 per cent of their previous value.

Research Work by the Institution of Mechanical Engineers

According to the annual report of the Council of the Institution of Mechanical Engineers, the Alloys Research Committee has continued its work and the eleventh report will be ready this year. The results of research at Sheffield on chemical and mechanical relations of iron, tungsten and carbon, and iron, nickel and carbon were presented in the form of a paper during the year. This work is being continued in connection with the carbides of cobalt and molybdenum. A paper on the former will shortly be presented. The Refrigeration Research Committee has presented its first report and is now conducting experimental work. The Wire Ropes Research Committee has collected a large amount of data and hopes soon to carry out tests. A committee is investigating the action of steam passing through nozzles and steam turbines, and the Brush Electrical Engineering Company has lent a three-flow condenser for the purpose. A research committee is investigating the question of a hardness test for hardened journals and pins. An advisory committee has been appointed to prepare a scheme for the co-ordination of research.

The Estimation of High Temperatures by the Method of Color Identity

Messrs. Paterson and Dudding's paper published in the April issue of the Proceedings of the Physical Society of London is modestly described by the authors as a preliminary note. Yet it is no idle praise to state that the paper represents original work of a very high order. Covering as it does some thirty printed pages abstraction is not easy. The general contents are best indicated by the following extracts of the authors' synopsis:

1. Preliminary experiments are described on the method of "color identity" adapted to the estimation of the temperature of incandescent substances such as metal or carbon radiating in the open: by this method the "true" temperature of certain bodies as distinct from their "black-body" temperature can be arrived at with a very fair degree of accuracy.

2. By the color identity method the total luminous radiation (white light) from a black body is made identical in color with that from the incandescent metal under examination by adjusting the temperature of the black body until there is color identity in the field of a Lummer-Brodhun photometer.

3. Comparisons are made of the results so obtained with those obtained by other methods and the color identity method is shown to give the correct result for melting platinum.

4. An explanation is given of the principal factors and limitations of the color identity method in which it is shown that accurate results should be obtained so long as the bodies under consideration act as "grey" bodies throughout the visible spectrum and that there will be a tendency to error to the extent that they depart from the grey body condition in the visible spectrum.

Laboratory Glassware

A most invaluable piece of investigatory work of great and immediate industrial value forms the subject of a short report just issued by the Council of the Institute of Chemistry. This summarizes the work of the Glass Research Committee appointed last October to conduct investigations with a view to arriving at suitable formulæ for the use of manufacturers willing to assist in maintaining the continued supply of laboratory glassware.

The chief aims of the research have been: (1) To produce working formulas for all glasses used in laboratory work, and (2) to ascertain the influence of various ingredients on the physical and chemical properties of glasses. The work was extended to include glasses for miners' lamps following the suggestion of the Home Office; and also glass for ampoules, to meet the needs of wholesale pharmaceutical chemists engaged in the production of army medical products. The committee have also examined and reported on samples of British and French laboratory glassware, produced since the beginning of the war, a number of the specimens being made from formulas similar to, and in some cases almost identical with, those recommended by the committee.

The committee have had before them many specimens of glasses used for various purposes of which analyses have been made by Mr. Blount, Mr. Hancock, and Mr. Heyner. It has been found, however, that mixtures prepared in accordance with the analytical results were not always satisfactory, but the analysis was helpful in suggesting synthetic experiments, and during recent investigations some intricate analyses made by Mr. Gilbert J. Alderton, under the supervision of Mr. Blount, have proved especially valuable. Apart from the analyses, the work has been almost entirely carried on at King's College by Professor Jackson and Mr. Merton, and by the former at his own house. The work has evolved a careful study of the chemistry of silicates, aluminates, borates, etc., in their relation to the manufacture of glasses. A detailed report of these experiments will be published in due course.

Up to the present time the research committee have reported eleven formulas for glasses for various purposes, based on the results of about 400 experimental melts on a scale large enough for drawing rods and blowing small vessels. In addition, a very great number of experiments have been made in order to study the influence of the various constituents employed. No formula has been issued without submitting the specimens made to rigorous tests to prove their suitability for the purpose for which they are intended. Moreover, by varying the experimental working conditions, it can be said with reasonable confidence that the mixtures will prove equally satisfactory under the actual working conditions of a glass furnace. The question of workable temperatures has been carefully considered, and so far as it is possible to judge, the melts on a small scale indicate that even better results will be obtained on the industrial scale. This view has been justified by the samples already received from manufacturers who have tried some of the formulas.

In deciding the formulas it has been found necessary to pay special attention to the proportion of basic and acidic substances in respect of the action of glass mixtures on clay crucibles during fusion, and it has been shown by careful investigation that the formulas pro-

posed give melts in which the influence of the ingredients of the crucibles is very slight, and in some cases practically inappreciable.

The Iron and Steel Institute Meeting

THE FIRST DAY'S MEETING

It is not unknown in the chronicles of scientific institutions that a president should be unable to read his presidential address. But the *force majeure* has generally been a matter of the ruling of medical advisers rather than that of one's King's enemies. The stress of war kept Monsieur Adolphe Greiner from presiding at the May meeting of the Iron and Steel Institute this year. Indeed there was no presidential address, but after the formal business of the meeting first place was given to a paper by M. Greiner. Formal business under the chairmanship of Dr. Arthur Cooper included the annual report of the council indicating a satisfactory financial year, the announcement of the postponement *sine die* of the International Congress of Mining and Metallurgy, the presentation of the Bessemer Medal to M. de Fleurer, attaché to the French embassy, on behalf of M. Pierre Martin.

Mr. ADOLPHE GREINER'S paper was then read—it was a brief but interesting note on **"The Heating of an Open-Hearth Furnace by Means of Tar"**—interesting not only technically but because of the circumstances leading to the solution of a fresh problem. In the author's words: "After the total stoppage of the works entailed by the foreign occupation, and once the preliminary period of disorganization had passed it appeared to us that we had a pressing duty before us—that of helping the working class population around us to the utmost extent of our power to earn its livelihood. For this reason I decided to undertake at once the manufacture of a portion of the orders we carried on our books so far as circumstances would allow.

The steel works were thus compelled to contemplate the necessity of relighting an open-hearth furnace. Our reserves of gas coal had been speedily exhausted; the only battery of coke ovens which was working was unable to furnish us with gas, of which it was itself in pressing need; the importation of British coal was impossible, and, as a matter of fact, we felt the need of freeing ourselves from the long established dependence of the works upon foreign countries as regards the supply of gas-coal. There remained as our sole resource the tar from the coke ovens.

In the present arrangement the tar is delivered to the sprayers (one only in each burner) with a regular feed and under a uniform pressure of half an atmosphere. It is sprayed by means of air compressed at about three atmospheres. The hot air of combustion is admitted above the injector through the existing port inclined at an angle of 45 deg. The average consumption of tar throughout the whole campaign has been 133 kg. (293 lb.) per ton of steel, including in this figure the amounts required for lighting up and for heating during stoppages. On the other hand, with an uninterrupted run this average falls to 115 kg. (253 lb.) per ton of steel. The average weight of the charges had to be diminished in order to avoid any deflection of the jet of flame issuing from the pulverizer toward the crown of the furnace. Nevertheless, several charges of 15 tons have been worked successfully without any other inconvenience than a proportionately longer working time. The proportion of pig-iron found necessary in the charge rose to 28 per cent.

I may add, after these 215 charges, the furnace is still in an excellent working condition. The roof appears even less damaged than after a similar campaign with coke-oven gas; only the chambers became encrusted. The bricks of the checker work became covered with a carbonaceous substance, and it will be necessary to devise some means of remedying this inconvenience.

This paper was not discussed, Dr. Cooper remarking that it was really an addendum to Mr. Greiner's paper of last year. A hearty vote of thanks was accorded together with an acknowledgment of the value of his service and hopes for his continued activity.

The second paper, by Sir ROBERT HADFIELD and Dr. GEORGE K. BURGESS of the Bureau of Standards, Washington, on **"Sound Steel Ingots and Rails"** evoked a lengthy and spirited discussion. This was opened by Mr. B. Talbot, who criticised the authors for having based their standards on a comparison of special acid open-hearth ingots with ordinary acid Bessemer ingots instead of with basic open-hearth ingots. Mr. Talbot also asked for an explanation of the statement that casting big end up was superior to casting with the small end up, which was the invariable custom in rail and many other steel works. While Sir Robert's conclusion might be correct for small ingots, it was doubtful if it was safe to dogmatize for all sizes of ingots. He had had some photographs prepared of ingots of a weight in common use in rail works—namely, some 3½-ton ingots—in order to see what the results really were. As Sir Robert used a refractory top on his mould, he had done the same, so as to make a fair comparison. Personally, he was a believer in the brick-lined top when it was desired to reduce the piping in the ingot, or, at any rate, to bring the pipe nearer to the top, and it was to the use of that well-known device that he attributed Sir Robert's better results, rather than to his special blow-pipe arrangement, which he used in addition.

Mr. C. E. Stromeyer expressed the opinion, in regard to failures in steel plates, that these failures were largely due to the use of Bessemer steel scrap in the open-hearth furnaces, and that was one reason for which he welcomed the paper. In a general way, the question of piping and that of quality should, he thought, have been kept separate; the method might not improve the quality, although it might reduce the piping. Fractures in rails were not due to piping, but to defective material. Bad qualities of steel were very much worse at cold than at ordinary temperatures. He did not think the method would improve the quality, although it would reduce the piping.

Mr. W. H. Hewlett said that segregation was a very detrimental occurrence, and as Sir Robert Hadfield by his method reduced segregation he was rendering a very great service.

Mr. F. W. Harbord expressed the same opinion, adding that they welcomed any process which gave sounder ingots, and the reduction of blow holes was what all steel manufacturers had been aiming at. The proportion of seconds seemed to him very high, and he would have liked the figures to have been given for the American ingot also.

Mr. T. Twynam asked whether Sir Robert Hadfield had found an increase in the carbon content of the metal just below the cavity; in other words, did there occur carbon impregnation? He (the speaker) said he had found impregnation to occur, and he wanted to know whether the author had had the same experience. A segregation of carbon at that part was dangerous.

Sir Robert Hadfield, in replying to the discussion, said that he would be very pleased to reply fully to all remarks by correspondence. If Mr. Talbot made an ingot exactly on the lines indicated in the paper, he would obtain about 90 per cent of good work. The specimens of sound ingots he had exhibited in the rooms were all of converter steel. The War Office and Navy specifications were most difficult specifications to meet;

in order to show the success of his method of manufacture, he added that ingots manufactured by his firm to the number of 120 had been cut through, and not one had been found defective. The ingots in question were representative of makes which extended over a period of from seven to eight months. If Mr. Talbot obtained similarly good results, he (Sir Robert) would be the first to congratulate him. When casting the larger end upwards, he (the author) added that there was a large ferro-static pressure, and a better result was obtained. In regard to Mr. Stromeyer's remarks, Sir Robert stated that his method of manufacturing the ingots did certainly lead to the manufacture of better rails, as was evidenced by the etchings. In the matter of carbon impregnation, when 9 to 10 per cent discard was cut off, all trace of carbon impregnation was removed with the discard; if it were not so, the British Government would have rejected material for that reason, and so far there had been no rejection in a total quantity of about 70,000 tons of ingots made in the manner described.

Comments on the second day's proceedings are held over to my next issue.

Market Prices

MAY, 1915

Tin showed a downward movement at the beginning of the month, but stronger in the last fortnight. It opened £159.10, rose sharply to £162.10 (3rd), dropped to £160.10 (4th), then rose to £165.10 (10th), fell slowly to £162.10 (14th), and after a slight rise declined to £160.10 (19th). It then improved to £164 (25th), but fell away again after to £162 (26th) and closes £163.5.

Copper opened £76 and rose smartly to £79.10 (7th). It then dropped to £77.12.6 (11th), but recovered to £79.15 on the 12th. Declining slowly it touched £75.5 on the 19th, but recovered to £76.17.6 on the 20th. On the 21st it was again £75.7.6. It then rose decidedly, being £78.15 by the 28th, and closes £79.2.6.

Haematite has been 95/- throughout the month.

Scotch Pig opened 70/- and after rising to 70/10½ on the 6th was inclined to weaken, being down to 69/3 on the 10th. It then appreciated to 71/4½ on the 12th, but went lower to 69/10½ on the 14th, recovering to 71/- on the 17th. It kept at 71/1½ after the Whitsun holidays till 25th, rising to 71/9 on the 26th.

Cleveland opened 64 - and rose to 66/10½ on the 6th, then dropping to 64/7½ on the 11th and 55/4½ on the 12th. On the 14th it was 63/10½; it then recovered to 65/7½ (25th), but subsequently went lower, closing 65/7.

English Lead opened £21, then dropped to £20 (5th), sharply recovering to £21.5 (7th), and keeping between £20.15 and £21, and closes £21.10.0.

	£	s.	d.
Aluminium, ingots, ton lots	90	0	0
Antimony, Blk. sulphide powder, ton	70	0	0
Borax, British refined crystal, cwt	22	0	0
Copper sulphate, ton	29	0	0
Caustic soda, 70 per cent ton	10	2	6
Ebonite rod, lb	..	3	0
Hydrochloric acid, cwt	..	4	6
India rubber, Para fine, lb	..	2	7½
Mica in orig. cases, medium, lb	..	3 to 5	0
Quicksilver (Spanish), bottle	12	2	6
Sal-Ammoniac, cwt	49	0	0
Sulphur, recovered, ton	8	0	0
Shellac, cwt	3	5	0
Platinum, oz. nominal	9	5	0

An antimony refinery is reported under construction at Harbor Industrial City, Cal. The capacity is said to be 1500 tons per month, and the operating company is reported to be producing ore from desert claims in southern California.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Concentration of Gold in Bottoms in the Copper Converter.—A method of recovering the gold in converter copper not rich enough to warrant electrolytic refining, is described by Mr. H. F. Collins in *Bulletin* No. 128, Inst. Min. & Met. The process has been standard practice at Cueva de la Mora since November, 1914. The operation depends on the incomplete oxidation of white metal to "pimple" metal and "bottoms," and separation of the latter before completing the oxidation. The author has adapted it to 3-ton acid-lined converters by providing a cast-iron tapping block opposite the tuyeres, having a tap-hole 1½ in. in diameter.

"When the lining is being rammed this hole has an ordinary ⅞-in. steel bar pushed through up to within an inch of the mould, so that the lining may be rammed round it as tightly as possible, and when the moulds are removed the bar is at the same time withdrawn in order to facilitate 'drying out.'

"When the converter is placed upon the stand for use the tap-hole is closed by a plug of clay, and a short ⅞-in. bar is then driven in so as just to protrude on the inside of the lining while the head stands out some 16 to 20 in. from the front of the converter shell. After blowing to precipitate as metal the required quantity of copper, the converter is turned down till the bar stands at about 75 deg. from the horizontal.

"After knocking it in an inch or so in order to penetrate any skin of copper that may have formed on the inside, the usual ring and wedge are affixed, and the bar is driven out as quickly as possible by rapid blows; as its point leaves the converter shell the mould car held in readiness at the back is rapidly pushed forward, while the converter is at the same time turned until the tap-hole is vertical.

"After one, two or three moulds have been filled, according to the size of the charge, and the issuing stream is evidently white metal and not copper, the converter is turned up as rapidly as possible, the tap-hole being plugged with clay while in motion until the next operation, and blowing is restarted to finish the charge as usual."

The success of the operation depends on not losing too much time in skimming and not adding too much scrap after skimming, so that the reduced copper is at a temperature above the melting point of the pimple metal.

"As regards the concentration of gold in the bottoms, in practice it is easy to recover 70 per cent of the gold originally existing in the charge in the form of bottoms, amounting to 9 per cent of the total weight of converter copper produced, and 25 times as rich. The richness of the bottoms in gold depends upon the relative proportions of bottoms and residue bars from each charge."

The workmen apparently have no difficulty in becoming expert in operating the converter in the proper manner, and in securing bottoms of uniform weight and value.

"In order to obtain good results, it is necessary to hit the point of 'white metal' with considerable nicety before the final skimming prior to commencing the blowing for bottoms, since if the white metal is low and contains more than 4 per cent iron, as occasionally happens when the skimmer is either careless or timid, the time required for oxidation of the excess iron will vitiate the calculation of that required for blowing to 'bottoms'; and insufficient copper will be reduced. Pro-

vided, however, the point at which the white metal is skimmed be kept fairly uniform, it is only necessary to proportion the time for 'bottoms blowing' roughly to the size of the charge."

Assay of Gold-Bearing Cyanide Solution.—A method for this purpose that has been in long use at the St. John del Rey property, Morro Velho, Brazil, is published in *Bulletin* No. 128, Inst. Min. & Met., by Messrs. DONALD M. LEVY and HAROLD JONES. The method is based on the precipitation of the gold by means of zinc shavings, or a zinc-load couple, from the boiling solution, in the presence of suitable quantities of silver and lead salts. Sufficient silver is introduced to form a parting alloy in the button. The following stock solutions are used:

Silver Solution.—1 grain silver per 10 cc. Dissolve 36 grains silver nitrate in water, add sodium cyanide in small quantities till the precipitate first formed is just dissolved. Dilute the solution to 2½ liters.

Sodium Cyanide Solution.—10 per cent. Dissolve 250 to 260 grams sodium cyanide in 2½ liters of water.

Sodium Plumbite Solution.—Dissolve 65 grams lead acetate in water, add sodium hydroxide solution till the precipitate first formed just redissolves, then dilute to 2½ liters.

The quantity of solution taken for each test is one two-thousandth part of the I. M. M. ton (7000 grains, or 453.6 cc.), so that using the ordinary bullion assay weights for weighing the final gold the result is read off directly as grains fine gold per ton. "This volume of solution is poured into a flask of 1¼ liters capacity and the silver solution is added; for the rich solutions (before passing zinc-boxes), 15 cc. of the silver solution are used, for the poor solutions (after passing zinc-boxes) and for wash-waters only 5 cc.

"Next 10 cc. of the sodium cyanide solution are added, then 5 cc. of the plumbite solution, and the mixture shaken.

"Twenty grams of zinc-shavings are now placed into the solution and the contents of the flask gently boiled for half an hour and then filtered at once, through a 9-in. filter-paper, the clear filtrate being rejected. To the flask containing the residual zinc-shavings a little water is added (say about 20 cc., only just so much being required as will prevent the cracking of the flask by the drying and heat produced on the subsequent addition of acid), then 70 cc. of commercial hydrochloric acid. After the complete solution of the zinc the contents of the flask are poured onto the filter, flask and filter being subsequently well washed with water.

"The wet filter is now transferred to an assay crucible placed in the furnace, dried slowly and then simply carbonized at a moderate heat, and the pot withdrawn from the fire. The following fluxing charge is now added:

Red lead	12.5 grm.
Borax	22.5 grm.
Sodium carbonate	12.5 grm.
Sodium chloride	2.0 grm.
Flour	2.0 grm.
Powdered glass	2.0 grm.
Potassium nitrate	2.0 grm.

"The crucible is returned to the furnace and the charge run down in the usual manner, from twenty to thirty minutes being required to complete the fusion, after which the contents of the crucible are poured, the metallic button detached and cupelled in a small magnesite cupel, the resulting beads being rolled out and parted directly in the usual manner."

Zinc and Lead

Flotation at the Timber Butte Mill, Montana.—In a paper to be presented at the San Francisco meeting of the American Institute of Mining Engineers next September, Mr. THEODORE SIMONS gives many details of the design, construction and operation of the Timber Butte concentrator now treating Elm Orlu zinc ore. Since flotation plays an important part in the scheme of treatment at this mill, the information given on that point is timely. The ore contains zinc, lead, copper, gold and silver. The gangue minerals are quartz, barite, fluorite, rhodonite and rhodocrosite. The ultimate aim of the treatment process is to produce three classes of concentrates suitable for copper, lead and zinc smelters. Table I gives the metallic contents of crude ore and mill products.

TABLE I.—AVERAGE ANALYSIS OF CRUDE ORE, CONCENTRATES AND TAILINGS

Name of Product	Cu Per Cent	Ag oz. per Ton	Au oz. per Ton	Fe Per Cent	Zn Per Cent	Pb Per Cent	Insol. Per Cent
Original ore	0.73	6.23	0.013	3.29	18.52	0.75	62.23
Copper-iron conc.	2.25	21.01	0.04	19.78	22.78	13.01	2.30
Lead-iron conc.	1.13	18.91	0.04	9.99	9.15	50.60	5.05
Coarse-zinc conc.	1.96	14.74	0.035	9.15	47.77	1.88	3.47
Fine-zinc conc.	2.22	16.84	0.036	4.45	52.44	1.72	5.05
Tailings	0.07	0.60	0.0017	0.44	1.20	0.05	95.42

The design and flow-sheet (Fig. 1) of the mill are the result of extensive tests. There are but two essential operations in the process: table concentration and flotation. Wilfley and James roughing tables make a lead-iron product rich enough for retreatment, and a finished zinc concentrate, the latter representing 25 per cent to 30 per cent of the total original zinc in the ore.

The mill proper consists of three separate buildings, connected by runways for conveyors and concentrate launders. The lower building, 155 by 70 ft. in size, contains the concentrate plant and bins, the coarse-ore bins and coarse breakers, the boiler plant and coal bins. The next higher building, 260 by 80 ft., contains the roll-crushing, table-concentration, and flotation plants. The highest building, 20 by 30 ft., contains the supply bin and feeders.

Rough concentration begins on No. 8 Wilfley tables, the feed ranging in size from 2.5 mm. to the finest product of crushing. Each table handles 100 tons of ore per day. In addition to the finished coarse zinc concentrate of about 50 per cent grade, several intermediate products are cut out for regrinding and further treatment by classification, jigging and concentration on Wilfley and James tables. The tailings from the James sand tables are reground for final separation of sulphides by flotation.

To unlock the finest included grains of mineral from Elm Orlu ore it is necessary to grind to about 60 mesh, and this is the maximum size of the flotation feed. The pulp is kept at a uniform density of three parts of water to one of ore, and is heated to a temperature of 130° F. by the introduction of live steam. Temperatures below 125° F. reduce the efficiency of the operation. Sulphuric acid also has been found essential, and is added at the rate of 7 to 8 lb. per ton of original ore. Oil is added at the rate of 0.5 lb. per ton. An outline of a cell of the Minerals Separation machine is shown in Fig. 2. Oil is introduced in the mixing compartment (*A*) of the first cell where the pulp is violently churned by the action of the agitator (*B*), which at this plant makes 265 rev. per minute and causes the propellers (*C*) to run at a peripheral speed of about 1500 ft. per minute. The aerated mixture passes through the opening (*D*) into the flotation compartment (*E*), where the froth containing the sulphides of lead, copper, zinc and iron, as well as some of the richer middlings, immediately rises to the surface, while the clean gangue and the leaner middlings drop to the bottom.

The flotation compartment has the shape of a spitz-

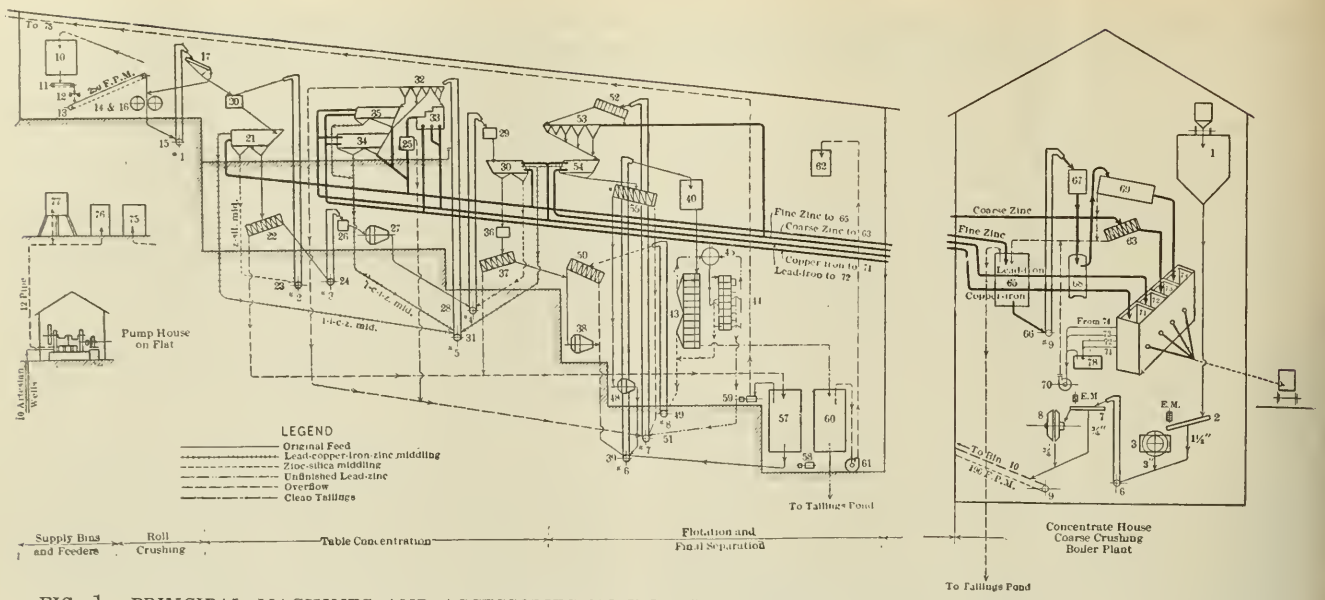


FIG. 1—PRINCIPAL MACHINES AND ACCESSORIES IN THE CONCENTRATOR OF THE TIMBER BUTTE MILLING CO., SHOWN ON FLOW SHEET

Flow Sheet Number	Number of Pieces	Description of Machine
1	2	Crude-ore bins, 750 tons combined capacity.
2	1	Shaking-screen feeder, 1½-in. square openings.
3	1	15 by 30 in. Farrel jaw crusher, crushing to 3 in.
6	1	Steel elevator, 32-ft. centers—95 ft. per minute.
7	1	3 by 8-ft. Symons pulsating screen, 375 strokes per minute, ¾-in. round openings.
8	1	Symons 36-in., style C disk crusher, 133 and 300 rev. per minute, crushing to ¾ in.
9	1	24-in. inclined belt conveyor, 196 ft. per minute.
10	1	Secondary ore bin, 1200 tons capacity.
11	4	24-in. steel apron feeders, 5 ft. per minute.
12	1	20-in. horizontal belt conveyor, 250 ft. per minute.
13	1	20-in. inclined belt conveyor, 250 ft. per minute.
14	1	54 by 18 in. Garfield rolls, 83 rev. per minute.
15	1	No. 1 belt elevator, 84-ft. centers, 415 ft. per minute.
16	1	54 by 18 in. Garfield rolls, 83 rev. per minute.
17	4	C.I.W. impact screens, 50 strokes per minute, 2½-mm square openings.
20	1	Eight-compartment mechanical distributor, 21 rev. per minute.
21	8	No. 8 Wilfley roughing tables, 243 strokes per minute.
22	2	45-in. Akins classifiers, 5 rev. per minute.
23	1	No. 2 belt elevator, 72-ft. centers, 400 ft. per minute.
24	1	No. 3 belt elevator, 50-ft. centers, 400 ft. per minute.
25	1	Dewatering box.
26	1	Three-compartment distributor.
27	3	8-ft. by 30-in. Hardinge mills, 28 rev. per minute.
28	1	No. 4 belt elevator, 58-ft. centers, 400 ft. per minute.
29	1	Eight-compartment mechanical distributor, 21 rev. per minute.
30	8	No. 3 James sand tables, 262 strokes per minute.
31	1	No. 5 belt elevator, 80-ft. centers, 400 ft. per minute.
32	1	Five-spigot Richards hindered-settling classifier, 40 tons capacity.
33	1	Double, three-compartment Harz jig.
34	2	No. 6 Wilfley tables, 240 strokes per minute.
35	1	No. 3 James sand table, 262 strokes per minute.
36	1	Distributing box.
37	2	45-in. Akins classifiers, 5 rev. per minute.
38	2	8-ft. by 30-in. Hardinge mills, 28 rev. per minute.
39	1	No. 6 belt elevator, 58-ft. centers, 490 ft. per minute.
40	1	16 by 10 ft. sludge tank, 10 rev. per minute.
43	1	Standard Minerals Separation 11-cell flotation machine, capacity 600 tons.
44	1	Standard Minerals Separation 8-cell flotation machine, capacity 200 tons.
45	1	Air lift.
48	1	4½-ft. Hardinge mill, 32 rev. per minute.
49	1	No. 8 belt elevator, 58-ft. centers, 490 ft. per minute.
50	3	45-in. Akins classifiers, 5 rev. per minute.
51	1	No. 7 belt elevator, 81-ft. centers, 490 ft. per minute.
52	1	Esperanza classifier, 25 ft. per minute.
53	1	Five-spigot Richards hindered-settling classifier, 100 tons capacity.
54	7	No. 3 James sand tables, 265 strokes per minute.
55	1	30-in. Akins classifier, 5 rev. per minute.
57	1	36-ft. Dorr thickener, 1/10 rev. per minute.
58	1	Cameron steam pump.
59	1	Cameron steam pump.
60	1	36-ft. Dorr thickener, 1/10 rev. per minute.
61	1	Two-stage centrifugal pump 1½ in.
62	1	10 by 10 ft.. hot-water tank.
63	1	45-in. Akins classifier, 5 rev. per minute.
65	2	28-ft. Dorr thickeners, ¼ rev. per minute.
66	1	No. 9 belt elevator, 52-ft. centers, 440 ft. per minute.
67	1	14 by 10 ft. agitating tank.
68	1	8 by 15½ in. Monteju tank.
69	1	Kelly filter press, type 850.
70	1	Two-stage centrifugal pump.
71	2	Copper-concentrates bins.
72	2	Lead-concentrates bins.
73	2	Coarse-zinc concentrates bins.
74	2	Fine-zinc concentrates bins.
75	1	30,000-gal. dirty-water tank.
76	1	30,000-gal. fresh-water supply tank.
77	1	50,000-gal. sprinkler tank for fire protection.
78	2	Settling boxes in concentrate house.

kasten, the apex of which is provided with a valve (*F*), adjustable by a hand wheel (*G*). Through this valve the material that has settled to the bottom of the first cell is drawn into the adjoining cell by the pumping action of its propeller. The process is here repeated and sulphides which did not float in the first cell are given a chance to do so in the second one, and so on.

The agitating compartments of the flotation cells are lined with cast iron, and the propellers are made of brass. All agitators of a standard machine are driven from one main shaft by gears which are protected from dust by steel housings. Gears are placed so that propellers in adjoining cells revolve in opposite directions, thus equalizing the strains on the machine and the power transmission.

The following statement gives in detail the flow of ore through the flotation section:

"From the sludge tank (40), which acts as an equalizer between the gravity-concentration and flotation section, the pulp flows to a standard 600-ton Minerals Separation unit (43) known as the 'rougher machine.' It consists of eleven cells, each divided into a mixing or agitating and a flotation compartment. The intensely agitated pulp discharges from the mixing into the flotation compartment, where the pulp is comparatively still and where a portion of the sulphide minerals rises to the surface to be skimmed off by revolving paddles and discharged into a launder in front of the cells. The remainder of the sulphides and the gangue that has settled to the bottom of each flotation

compartment are drawn into the adjoining cell by the pumping action of its agitator. Here the process is repeated and sulphides not floated in the first cell are given a chance in the second cell, and so on.

"The overflow from the last five cells of the 'rougher machine' (43) is a middling that goes via No. 8 elevator (49) to Akins classifiers (50). The classifier overflow returns to the 'rougher machine' of the flotation section. Sands are reground in two 8-ft. by 30-in. Hardinge mills (38) to an approximate 60-mesh maximum size and return via No. 6 elevator (39) to flotation section.

"Finished tailings from the eleventh cell of the 'rougher machine' (43) flow to a 36-ft. Dorr thickener (60) to be partly dewatered and thence to the tailings pond. The overflow from this tank is hot water, free from solids. It is pumped by a two-stage centrifugal

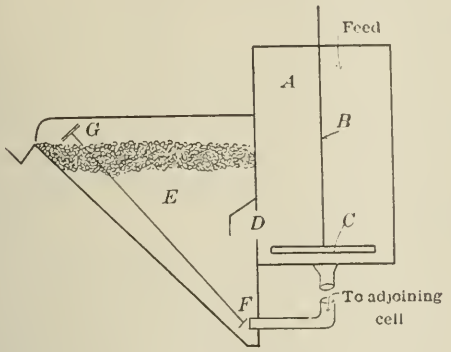


FIG. 2—OUTLINE OF M. S. FLOTATION CELL

pump (61) to a 10 by 10 ft. tank (62), which supplies the flotation machines with hot water.

"The mixed sulphide concentrate which overflows from the first six cells of the 'rougher machine' (43) goes via air lift (45) to a 200-ton Minerals Separation unit (44), consisting of eight cells, known as the 'finisher.'" Here the 'rougher' concentrates are refloated for the purpose of removing more of the gangue minerals. Cells Nos. 1—2—3—5—6—7 of this machine (44) make a float sulphide which goes via No. 7 elevator (51) to classifiers and James tables for final separation of lead and iron from the zinc.

"Overflow from cells 4 and 8 of 'finisher' (44) returns via air left (45) to the same unit. The bottom discharge from cells 4 and 8 is a middling which joins the middlings from the 'rougher machine' (43) to be reground in Hardinge mills (38) and returned to the flotation section.

"The float concentrates from unit (44) are lifted by No. 7 elevator (51) to an Esperanza classifier (52), the overflow from which is a finished fine zinc concentrate that goes to two 28-ft. Dorr thickeners (65) in the concentrate building. Sands go to a five-spigot Richards hindered-settling classifier (53), whose overflow is a finished fine zinc concentrate, which joins the overflow of the Esperanza classifier.

"The discharge from the five spigots of the Richards classifier is distributed on seven No. 3 James sand tables (54), where the lead and zinc are separated and the insolubles in the zinc concentrate reduced to about 3.5 per cent. Each table makes the following products:

"1. A finished lead concentrate, which goes to bin (72).

"2. A lead-copper-iron-zinc middling, which is returned via No. 5 elevator (31) to the primary jig and table retreatment circuit.

"3. A fine zinc concentrate, which goes to Dorr thickeners (65) in the concentrate building to be partly dewatered.

"4. A tailing, which is reground in a 4½-ft. Hardinge mill (48) after passing through a 30-in. Akins classifier (55) whose overflow returns via No. 7 elevator (51) to the final table-separation circuit.

"The product of the Hardinge mill (48), which is of about 60-mesh maximum size, goes to flotation section via No. 6 elevator (39).

"The Dorr thickener (57) receives practically all the fines and slimes coming from the mine and those made in the crushing operations. The overflow is dirty water, which is pumped by a double Cameron steam pump (59) to the 'dirty-water tank' (75) at the top of the mill, whence it returns for circulation throughout the mill. A duplicate auxiliary Cameron pump (58) is put into service whenever pump (59) is stopped for repairs. From the bottom of tank (57) the thickened pulp is lifted by hydrostatic pressure to the boot of No. 6 elevator (39) to go to flotation section."

Taking the mill as a whole, the ratio of concentration for zinc is 2.89, and for lead and iron 125, approximately 20 per cent of which is lead concentrate. Treatment costs have averaged between $2 and $2.25 per ton of crude ore, including labor, power, water, supplies, repairs and general expenses, but not interest on investment or depreciation. Extraction is about 96 per cent for zinc and 92.6 per cent for silver.

Recent Chemical and Metallurgical Patents

Copper and Zinc

Leaching Copper with Ammoniacal Solutions.—The proposed method of leaching metallic copper from the tailings at the Calumet & Hecla, in Michigan, is disclosed in a patent granted to Mr. C. H. BENEDICT, metallurgist for the company. A brief statement of the

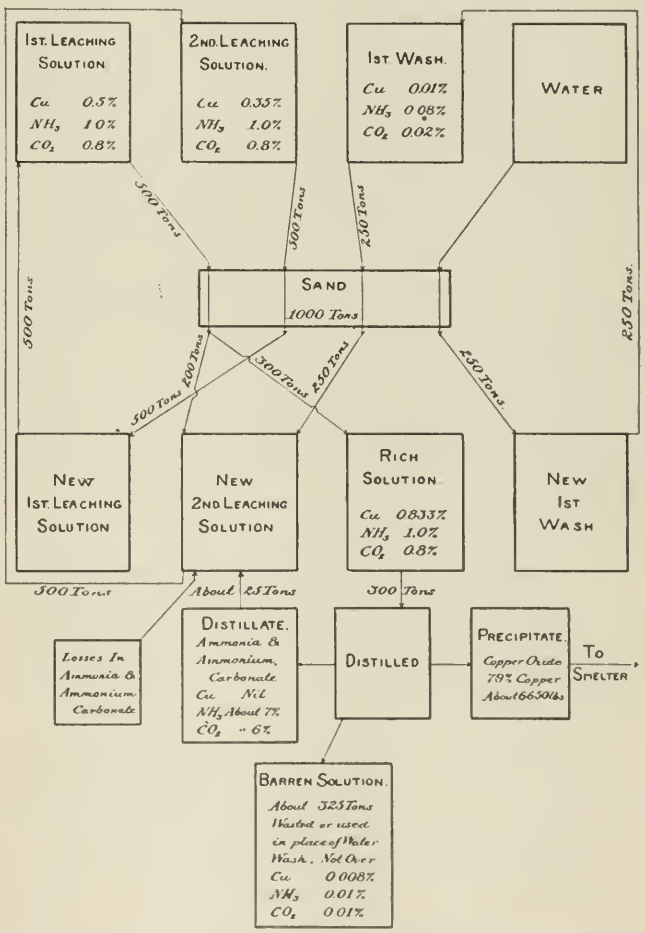


FIG. 1—AMMONIA LEACHING PROCESS FOR METALLIC COPPER ORES

process appeared in Metallurgical and Chemical Engineering for April, 1915, page 233. The flow-sheet of the process is represented in the accompanying Fig. 3. In view of the interest in the process, we give an extended abstract of the patent specifications, which are unusually instructive and complete.

"It has long been recognized that—(1) copper oxide will dissolve in ammoniacal solutions, yielding copper-ammonium compounds; (2) solutions of cupric-ammonium salts are capable of dissolving native or metallic copper, yielding cuprous-ammonium salts; (3) these cuprous-ammonium salts may be oxidized, by air or other suitable oxidizing agents, to cupric-ammonium salts; and (4) copper-ammonium solutions subjected to distillation are decomposed with separation of copper oxide, ammonia being volatilized." The difficulties encountered in applying these ammoniacal solutions to copper extraction in a commercial way have been the heavy loss in ammonia and the high cost of apparatus adequate to prevent such losses. According to Mr. Benedict's investigations, he is of the opinion that the loss of ammonia is not due exclusively to volatilization, but to adsorption of ammonia by the fine sands and especially by slimes. He has discovered also that this adsorption is generally proportionate to the concentration of ammoniacal solution, being less in dilute than in strong solutions. Thus, in solutions containing 2 per cent or less NH_3 in the free state, adsorption is so small as to be negligible from the aspect of commercial success.

"It is a primary object of the present invention so to operate a cyclical leaching-process as to render it practicable to use these highly dilute ammoniacal solutions of copper for solvent purposes, securing thereby the advantage of small or negligible losses of ammonia and of copper, without unduly increasing the cost and size of the installation. To this end, the cycle of operations is so arranged that an amount of copper equal to that extracted from a given batch of ore will be found concentrated in a relatively small proportion of the total volume of solution brought into contact with this ore. A suitable volume of this stronger solution is subjected to distillation to precipitate its copper-content in the form of oxid, and to recover the free ammonia and any volatile ammonium salts, which are restored to the cycle at the appropriate point, the volume so distilled preferably containing an amount of copper practically equal to the total quantity of copper extracted from the ore in the same cycle."

"The four typical solutions, as applied to a sand assaying approximately 0.5 per cent of copper, in the order of their application to the sand, are designated and characterized as follows, percentages being by weight:

(1) "First leaching solution": 0.5 per cent Cu: 1.0 per cent NH_3: 0.8 per cent CO_2.

(2) "Second leaching solution": 0.35 per cent Cu: 1.0 per cent NH_3: 0.8 per cent CO_2.

(3) First wash": 0.01 per cent Cu: 0.08 per cent NH_3: 0.02 per cent CO_2.

(4) "Second wash": Water, or a distillation reject containing only traces of copper and ammoniacal compounds."

"Sand finer than forty mesh, previously freed from slime by means of a Dorr classifier or otherwise, is run into a tank which for illustrative purposes may be 54 ft. in diameter by 12 ft. high. This tank should be covered, fitted with valve-controlled vents, provided with a false bottom of filter-cloth supported on a wooden frame and fitted with an overflow and with appropriate means for receiving and delivering the sand and the various solutions. The sand is run in with water in such manner as to be uniformly distributed. After one thousand tons of sand have been delivered to the tank, filling it with sand to a height of about 10 ft., the water meanwhile overflowing, the excess water is removed by decantation and the sand drained to the surface. The first bleaching solution is then led into the tank from above, the bottom valve opened, and the water displaced at as rapid a rate as filtration will permit. As soon as ammonia begins to appear at the outflow, indicating substantial displacement of the water, the lower valve is partially closed and the percolation rate adjusted as may be found necessary to secure a satisfactory solution of the copper-content of the ore. The first portions of the solution are found to be poor in copper and low in ammonia-content, owing to diffusion and imperfect displacement, and are run into the sump for the second leaching solution. Soon the first leaching solution, properly enriched in copper and now termed 'rich' solution, appears and is permitted to flow to the 'rich' solution tanks for subsequent distillation. This 'rich' solution is the richest portion of the effluent coming from the sand, and is ready for distillation. The volume of rich solution distilled for any one batch of sand is dependent upon the copper-content of the sand, and in practice will be, on the average, such volume that the copper-content of the rich solution distilled is practically equal to the copper extracted from the sand. The rich solution on distillation breaks up into copper oxid for the smelter, ammonia and ammonium carbonate for the second leaching solution, and a reject containing traces only of copper, ammonia and ammonium carbonate; this reject may be used instead of water for the second wash if desired."

"As soon as the first leaching solution, amounting in all to some five hundred tons, has been run upon the sand and has reached the sand line, the second leaching solution is run in, in approximately equal volume; and when this in turn has all reached the sand line, the first wash is added, followed in the same manner by the second wash, the effort in all cases being to avoid mixing solutions, and to displace each by that next succeeding it in the cycle. The several effluent solutions are so manipulated as practically to maintain the proper composition balance, as between the chemical contents of the various solutions, a typical method by which this may be done being illustrated graphically in the diagram before referred to. There is thus established an equilibrium in the process, there being also a regular progression of solutions in the following general manner: The second wash of charge N takes up a little copper and becomes the first wash of charge $N + 1$; this in turn takes up a little more copper and receives the distillate and some dissolved copper from previous cycles and becomes the second leaching solution of charge $N + 2$; the free ammonia of this second leaching solution is partially used in dissolving copper, when it becomes the first leaching solution of charge $N + 3$, its copper content having been fully oxidized to the cupric condition; this first leaching solution having become saturated with copper by its passage through the sands, and having thereby lost its solvent power, is in part distilled, as before described, depositing its copper values as a 79 per cent oxid, yielding its ammonia and ammonium carbonate as a pure product to join cycle $N + 4$ as a second leaching solution, and furnishing from its almost barren reject a second wash for a following cycle. In a plant containing more than one leaching tank, these several operations are of course all going on at the same time, the total volume of solution in circulation being practically a constant: thus "rich" solution is continuously withdrawn from the leaching circuit, and is replaced by an equal volume of

oxidation through the surface contact of the dilute solutions with the atmosphere, particularly after the process has reached the desired equilibrium, so that relatively large amounts of copper are being carried in solution.

"It is accordingly quite unnecessary, as a rule, in the regular operation of the process, to use any system of mechanical aeration of the several solutions. These are stored in covered tanks, with controlled vents, whereby air may be admitted as required. Means for injecting air under pressure may also be fitted both to the storage and leaching tanks. It has further been shown, in practice, that whereas there is some appreciable adsorption of ammonia by the sands, even from solutions so dilute as those contemplated under the present invention, the adsorption of copper is practically nil; and the losses of copper are materially reduced by the employment, as described, of at least two leaching solutions, applied successively, the second leaching solution being poorer in copper than the first, and both solutions being highly dilute.

"Obviously, the loss due to ammonia adsorption may be somewhat lessened by repeated washings, and it is possible and may be advisable to have a 'third wash' following the 'second wash,' the expediency of this being a commercial circuit of pipes, pumps, storage room, and the like. So, too, the balance between the amount of 'rich' solution distilled and 'second wash' used is in part a commercial one, depending upon the cost of steam and the distillation loss, as against the recovery of additional copper and ammonia by more complete washing."—(1,131,986, Mar. 16, 1915.)

Copper Hydrometallurgy.—Improvements in the treatment of such copper ores as chalcopyrite and chalcocite, by roasting, leaching and electrolysis are contained in a process patented by Mr. E. A. CAPPELEN SMITH of New York City. In the roasting process the ore is treated in a furnace of the Wedge or Herreshoff seven-hearth type, at a temperature of between 600 deg. C. and 750 deg. C. in the first five hearths and between 450 deg. C. and 500 deg. C. in the last two hearths. In

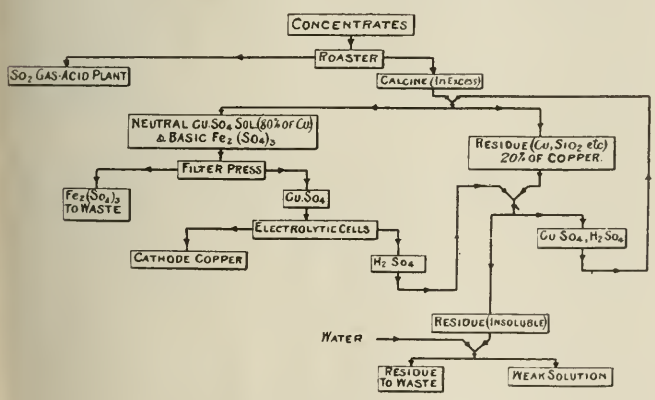


FIG. 1—COPPER LEACHING PROCESS

the hotter hearths sulphur is eliminated and FeO formed; in the last two cooler hearths the FeO is converted into Fe_2O_3. The copper compounds are completely oxidized, and the iron content is in a form practically insoluble in sulphuric acid.

The roaster gases are converted into sulphuric acid for leaching.

A diagrammatic flow sheet of the process is shown in Fig. 1. The process is cyclic, and is thus described:

"Assuming that the cycle of operations is fully under way, a quantity of partially leached ore from which about 85 per cent of the copper has been removed, in the step hereinafter referred to as the neutralizing leaching, is treated by agitation with the electrolyzed solution returned from the electrolytic vats. The solution thus employed will contain usually about 10 to 12 per cent of free sulphuric acid, and say from 1.5 per cent to 2.5 per cent of copper, according to the extent to which the electrolysis has been carried. Practically all the copper still remaining in the partially leached ore is taken into solution by this leach liquor, and also a very small amount of iron in the ferric state; the resulting solution is then drained into another agitating tank, where, in order to remove the ferric iron, a fresh batch of ore from the roasting furnace is added in sufficient quantity to neutralize practically all of the acid remaining in the solution. By this operation, the ferric iron taken up from the partially leached ore by the acid electrolyzed solution, is precipitated as a basic sulphate of iron, while about 85 per cent of the copper contained in the fresh batch of ore used in the neutralizing leaching is dissolved. The solution and the ore are then withdrawn to a settling tank, where the partially leached ore quickly separates out from the solution, which latter retains suspended therein, practically all of the basic iron salts. The solution is then immediately tapped off or siphoned off from the top of the ore before it has time to deposit any material part of its salts in the ore. It is then filter pressed, which removes the suspended iron salts and gives a clear electrolyte, almost devoid of iron salts, which electrolyte then passes to the electrolytic tanks.

In the electrolytic tanks, the copper is electrolyzed out of the solution between a practically insoluble or non-corrodible anode and a copper cathode. For the insoluble or non-corrodible anode, the usual lead anode, preferably having a small proportion of antimony may be employed. It has not always been possible to conduct the roasting operation in such manner that all of the iron present in the ore is converted into ferric iron; a small amount, say, less than 1 per cent, will usually remain as ferrous iron, and, in the leaching which follows, this ferrous iron being much more readily soluble in sulphuric acid than the ferric iron will enter the solution. After the ferrous iron is in the solution it will run through the operation up to the point of electrolysis. At a certain stage of the electrolysis, however, practically all of the iron present in the electrolyte is converted into ferric iron. If now it should be found desirable to remove the iron from the solution, the electrolysis can be stopped at this point and the solution can be used over again in leaching, whereupon, in the neutralizing leaching, all of the iron in solution which is now in the ferric state will be precipitated, even including the iron which originated from the ferrous iron present in the roasted ore. If the electrolysis is continued until the solution is very low in copper, the small amount of iron remaining dissolved in the solution will be reconverted into ferrous sulphate, which is not removable, as a basic sulphate in the neutralizing leaching." (1,134,767, April 6, 1915.)

A briquet for use in zinc furnaces is patented by Mr. GEORGE S. BROOKS of Depue, Ill., and assigned to the New Jersey Zinc Company. It is composed of four parts by weight of zinc ore crushed to the usual degree of fineness; one part of more finely powdered ore, or in lieu thereof, one part of commercial zinc oxide; one and one-half parts of powdered coal; and a sufficient quantity of common salt dissolved in water, to form a thick plastic mixture of the several ingredients. The amount of salt usually used is about 1½ per cent in weight of the ore in the mixture. The mixture is pugged and formed into briquets about 7½ in. in diameter and 7 in. long.

The briquets, in whatever way formed, are then subjected to about 90-lb. pressure per square inch. The briquets are kiln-dried for twenty-four hours at a tem-

perature of about 200 deg. F. During the drying the salt forms a crust or shell on the surface of the briquet, which protects it in handling and forms a filter about the ore through which the distilled zinc must pass. This results in a high production of spelter and a reduction in production of blue powder. The briquets are charged into the retorts by means of a semi-cylindrical chute long enough to contain enough briquets to fill the retort. With 50-in. retorts, six 7-in. briquets form a charge. The practice increases the capacity of retorts about 15 per cent to 20 per cent, and when the reduced quantity of blue powder requiring further smelting is taken into consideration, the capacity of a furnace treating briquets is increased 33 1/3 per cent. (1,137,835, May 4, 1915.)

Iron and Steel

Sintering Ores.—In a patent granted to Mr. Albert F. Plock of Pittsburgh, Pa., and assigned by him to the Pittsburgh Metallurgical Company, disclosure is made of apparatus for sintering ores. Fig. 2 shows the arrangement of apparatus. Cars 10 provided with grate bottoms are delivered from transfer trucks 6 to elevated tracks 2. The cars 10 successively pass under the ore

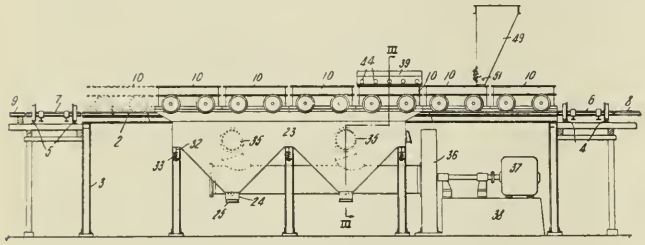


FIG. 2—SINTERING APPARATUS

hopper 49, receiving a charge of material to be sintered, thence into the furnace 39 where the top of the charge is ignited by means of gas or oil burners. On entering the furnace the cars register also with the suction box 23 placed below the tracks and connected with a fan 36 operated by a motor 37. While passing over the suction box the ignited charge is subjected to a downward draft, whereby the mass is sintered. When this operation is complete the car is delivered onto transfer truck 7 and removed to a point of discharge. No means is disclosed for mechanically moving the charge cars over the elevated track, nor for regulating the rate of travel. (1,140,710, May 25, 1915.)

Gold and Silver

Automatic Regulation of Pulp Thickening Apparatus.—In the operation of such apparatus as the Dorr continuous thickener, in which overflow and under-

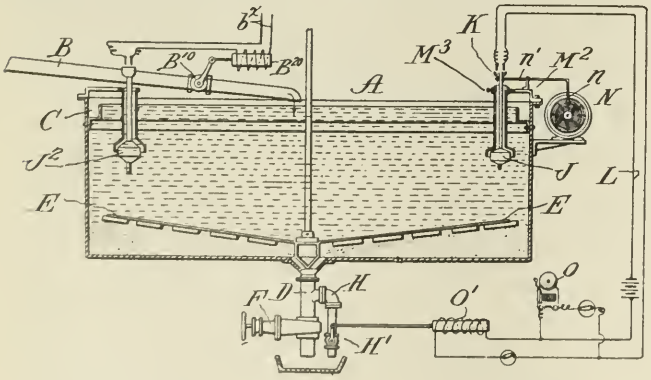


FIG. 3—REGULATION OF PULP THICKENING

flow products of certain character are sought, it is desirable that the apparatus should be operated in a uniform manner. With this object in view, Mr. J. V. N. Dorr of Denver, Col., has patented means for automatically giving warning when a change of density occurs in a selected zone of either product, and to regulate the discharge of the products for the purpose of maintaining constant conditions. Use is made of a hydrometer which rises and falls as the density of the liquid in a predetermined zone varies, and which may be made to operate mechanism to sound an alarm or regulate the apparatus, or both. The idea is illustrated in Fig. 2, applied to a Dorr thickener. A hydrometer J is adapted to close an electric circuit when the density of the liquid in a certain zone varies, and this circuit includes a bell or other alarm and a solenoid operating a discharge cock for the settled material. Recording apparatus N can be used by attaching a pen n by lever n' to the hydrometer. A similar hydrometer J^2 can be made to operate a cock on the feed line B by means of

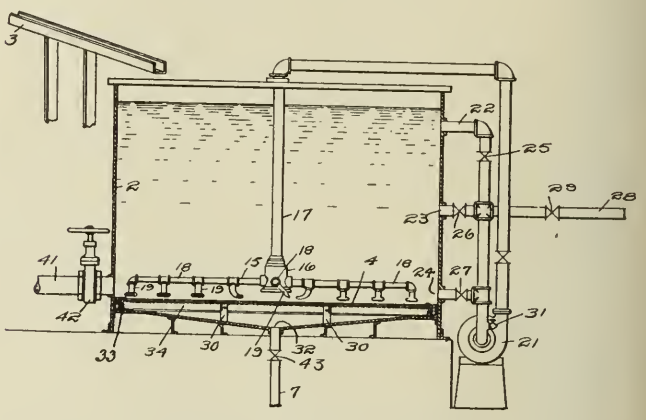


FIG. 4—FILTRATION OF SLIME

the solenoid as shown in the diagram. (1,140,131, May 18, 1915.)

Apparatus for Cyaniding Slime.—A method of treating slime pulps and separating the metal-bearing solution from the valueless gangue by filtration without forming a filter cake, is patented by Mr. Albert E. Vandercook of Alameda, Cal. Interest attaches to the process inasmuch as it is reported that it is to be adopted at two properties in California and Nevada. One of the mechanical features is illustrated in Fig. 4, being a vat in which the treatment and the filtration take place.

The vat has a filter bottom and is connected with a source of vacuum not shown. Within the vat is a distributing pipe and nozzles through which the slime pulp is forced by the centrifugal pump 21. The pump has three connections with the vat at 22, 23, 24, either one of which can be used while the others are closed. In operation the vat is filled with pulp which is circulated by the pump through the pipes and nozzles. The streams of pulp issuing from the nozzles sweep the filter surface and keep it free from accumulations. Filtration proceeds without the formation of a cake, and when the filterable liquid is practically removed and a thick pulp remains, wash solution or water is added through pipe 28.

The pulp is again thoroughly mixed and filtered as before. The operation may be repeated and the final thick pulp is sluiced out through pipe 41. (1,139,825, May 18, 1915.)

Smelting Process

Recovery of Elemental Sulphur.—A process for so operating smelting furnaces as to prevent the escape of noxious fumes, principally SO_2, and the production of elemental sulphur, is patented by Messrs. William F. Lamoreaux and Charles W. Renwick of Isabella, Tenn. The process is based on the reduction of SO_2 to sulphur

by means of carbon, and consists in passing the smelter fumes through an incandescent mass of coke. The electric current is used to heat the coke to the proper temperature and maintain uniform conditions. The temperature produced by the combustion of the coke alone in an atmosphere of sulphur compounds will not suffice to produce the reactions, as the product of combustion will mix with the smelter gases and vitiate the results. Hence the coke is heated electrically. The conversion from SO_2 to S depends on the temperature and length of time of contact with the coke. A temperature of 1300 deg. C. and a period of contact of five seconds accomplishes practically 98 per cent reduction. (1,140,310, May 18, 1915.)

Another process for accomplishing a similar purpose is patented by Mr. WILLIAM A. HALL of New York City. The reduction of SO_2 to S is accomplished in the smelting furnace by maintaining the top in as cold condition as practicable, by introducing continuously fresh ore to be smelted and by spraying the top of the ore with water. A portion of the water descends to a point where it is converted into steam, which reacts with the sulphide ore to form H_2S. This combines with the SO_2 present in the gases to form water and elemental sulphur, the latter being carried out in the gases and recovered in washers. (1,133,637, March 30, 1915.)

Metallurgical Furnaces

An improvement in hearths in roasting furnaces of the McDougal type is claimed in a patent to Messrs. JOHN H. KLEPINGER of Great Falls, Mont., and FRANK R. CORWIN of Douglas, Ariz. Instead of forming the hearths of numerous molded forms of refractory material, a monolithic structure of reinforced concrete is formed for each hearth. The construction is practically free from joints and uneven surfaces which, in the usual furnace, tend to weaken the hearth and increase the growth of accretions of fused particles. (1,140,042, May 18, 1915.)

The effective heating of the hearth of a roasting furnace by means of an electric current is the basis of a patent granted to Mr. UTLEY WEDGE of Ardmore, Pa. In a nine-hearth furnace, in which hearths 1, 3, 5, 7 and 9 are fixed, and 2, 4, 6 and 8 rotatable, electrical heating devices are applied to hearths 3, 5 and 7. Each of these hearths has sector-shaped recesses or chambers for the reception of electrical resistance blocks. Each recess is closed at its top to provide a continuous upper surface for the hearth, but is open below for the radiation of heat from the resistance block directly upon the material carried by the hearth beneath. (1,137,559, April 27, 1915.)

Sulphur Burner.—The Valley Iron Works Company, Appleton, Wisconsin, is now prepared to furnish the Vesuvius sulphur burner for producing pure sulphur dioxide gas in nine sizes from laboratory size to 9-ton capacity.

The **Clarage Fan Company,** Kalamazoo, Michigan, have opened a Cleveland sales office in the Rockefeller Building, Cleveland, Ohio. This office is in charge of Mr. R. G. Ferguson.

The **U. S. Blow Pipe & Dust Collecting Company** is the new name of the former U. S. Steel Tank & Pipe Co., exhaust-system contractors of 2090 Canalport avenue, Chicago, and 3000 N. Ninth street, St. Louis, Mo. The new name is more representative of their ever-growing business in shaving and fine dust collecting for woodworking, grain elevators, mills and all industries where dust and refuse are created.

Ore from the Boss mine, near Goodsprings, Nevada, containing the platinum group of metals, has been shipped to the American Smelting & Refining Co., according to a bulletin from the Mackay School of Mines. The shipment weighed 56,267 pounds and assayed as follows: Platinum, 1.1 oz. per ton; palladium, 5.47 oz.; gold, 8.75 oz.; silver, 9.0 oz.; copper, 0.97 per cent; insoluble, 80.7 per cent; sulphur, 0.5 per cent; iron, 6.7 per cent.

Welding Up Scrap Nickel Anodes

Some interesting experiments in the welding of nickel anodes by the oxy-acetylene process have just been concluded in the large plating department of The Prest-O-Lite Company, Inc., at its Indianapolis plant. As a result of these experiments and tests, worn nickel anodes which have previously been scrapped and sold at less than half price are now being reclaimed at a saving of more than 100 per cent.

The anodes used by The Prest-O-Lite Company, Inc., are castings of 90 per cent nickel, 8 per cent carbon and 2 per cent iron. They are elliptical bars approximately 1½ in. x 3½ in. cross section and 30 in. long and weigh about 30 lb. Their market value varies between 46 and 50 cents per pound. On the basis of the latter price, each 30-lb. anode has a value of $15.

By welding up old anodes which have been in the solution, and which have a junk value of between 22 and 25 cents per pound, The Prest-O-Lite Company, Inc., is now converting its entire pile of scrap nickel into what are practically *new anodes* at a total cost for gas

FIG. 1—SCRAP NICKEL ANODES WELDED TOGETHER

and labor of less than 6 cents per pound. This estimate is based on a recent test at Indianapolis in which 421 lb. of scrap anodes were welded up at the following costs:

463 cu. ft. oxygen, at 2 cents	$9.26
480 cu. ft. acetylene, at 2 cents	9.60
24 hours labor, at 25 cents	6.00
Total	$24.86

In view of the fact that this test was made before any experience in the operation had been gained, it is

apparent that better results and greater savings are sure to be the result of practice.

The method of handling this operation is as follows: As the anodes are eaten away by the solution they are turned over to an oxy-acetylene welder who "tacks" on scraps of old anodes by welding to increase the surface. One, two, three and sometimes four pieces of scrap are welded on, depending on the size and weight desired.

The welding flame is also employed to remove the brass hooks which are used to support the anodes while in solution. Under the intense heat of the oxy-acetylene flame (approximately 6,300 deg. F.) the solder melts away rapidly, leaving a pure nickel bar which is later welded up.

Thus, by the addition of from, say, 5 to 15 lb. or more of scrap nickel a brand new anode is manufactured at trifling cost and every bit of scrap is utilized without the loss of a single pound of metal. No flux is employed as this has been found to be unnecessary. The pieces of scrap are simply melted on or "fused" together, using another piece of nickel as a filling rod.

The welding process is a great benefit in obtaining perfect fusion, which is essential, as all joints must have electrical conductivity equal to that of new anodes.

Another great advantage is the fact that no skill or experience in the art of oxy-acetylene welding is required to weld up scrap nickel anodes—in fact, any workman with average intelligence can do the work without any previous knowledge of the process. The apparatus required to do the work is inexpensive.

Many previous attempts have been made to utilize scrap nickel anodes, the most common practice being to drill holes through several pieces and bind them together by means of lead rivets. This method depends upon the contact of the wire or rivet and the piece of scrap to conduct the current, and is therefore of uncertain value and in many cases a flat failure. If, for any reason, the contact is bad and offers too much resistance to the current of electricity, the metal might or might not dissolve. Therefore, by using the welded anodes as much scrap may be used in a tub as is desired without any danger of depleting the solution of metal.

The welding process solves an important problem in the nickel plating industry as hundreds of tons of scrap nickel anodes can now be utilized at the same value as new anodes and at trifling cost.

The Prest-O-Lite Company, Inc., estimates that more than a ton a year of scrap anodes can be used in its plating department.

The Course in High Temperature Measurements at Purdue University

BY ERVIN S. FERRY

Head of the Department of Physics.

Some half-dozen years ago the Department of Physics of Purdue University commenced the organization of a course in high-temperature measurements. The lack of standardization of equipment, as well as the lack of a text book or laboratory manual, necessitated a large amount of work premilinary to the admission of students. Much of this preliminary work was done by Dr. G. A. Shook, now of the University of Michigan. Since the departure of Dr. Shook the laboratory work of the course has been under the charge of Instructor J. R. Collins. As the course has emerged from the pioneer stage and now forms part of the required work of the students in our school of chemical engineering, it has been thought that a brief description would not be without interest to readers of *Metallurgical and Chemical Engineering.*

The course occupies one hour of lecture and five hours of laboratory work per week for one-half year. The lectures begin with a consideration of the ideal gas, the thermodynamic and the black-body temperature scales. Then follows a consideration of thermoelectric and resistance pyrometry. The methods of making the "cold-junction correction" as well as the practical means employed to diminish the magnitude of the error are discussed in some detail. The laws of radiation are taken up and discussed with especial reference to optical and radiation pyrometry. The methods of calibrating and using all the standard types of pyrometers are studied, as well as the availability of the various types for particular duties.

The furnace equipment includes three 20-kw tube furnaces, each connected to a separate transformer and switchboard (Fig. 1), a number of smaller electric

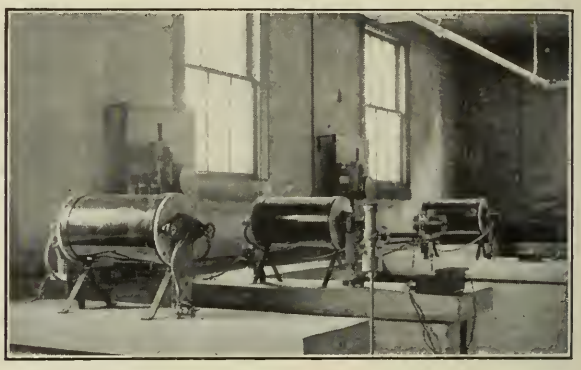


FIG. 1—TUBE FURNACES

furnaces, and a battery of five gas furnaces for 1-gal. crucibles (Fig. 2). Through the courtesy of the professor of practical mechanics our students also use the large oil furnaces belonging to that department. The laboratory maintains a Lummer-Kurlbaum "black-body," which, however, is no longer entrusted to student use.

The instrument equipment includes several types of thermoelectric pyrometers; resistance pyrometers having various types of bridges and potentiometers; radiation pyrometers according to Fery and Thwing; together with optical pyrometers according to Le Chatelier, Fery, Shore, Wanner and Holborn-Kurlbaum.

The list of experiments for the present year includes the ten determinations outlined below, followed by prac-

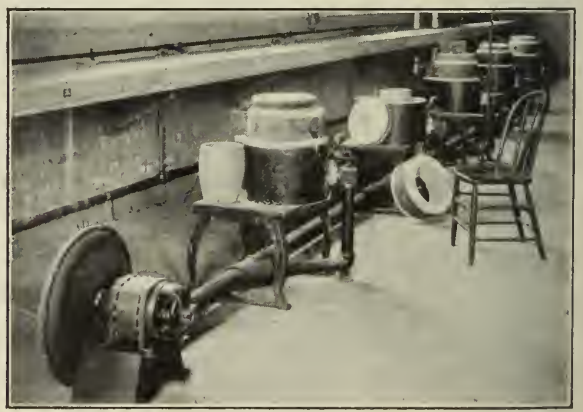


FIG. 2—GAS FURNACES

tical temperature determinations under shop conditions in the tempering room of the department of practical mechanics.

1. *Calibration of a Platinum-Rhodioplatinum Thermoelectric Pyrometer.*—The empirical curve is constructed by coördinating the known freezing points of five metals

or salts with the corresponding pyrometer indications. The equation of this curve is computed and the curve extrapolated.

2. *Construction and Test of a Base Metal Thermoelectric Couple.*—The two wires are wound with asbestos, coated with fireproof insulating material, the "fire end" fused, the wires annealed and tested for inhomogeneity. The calibration is made by comparison with a standardized platinum-rhodioplatinum couple. To exercise the student in making "cold-junction corrections" the cold junction of the standard thermoelement is maintained at a temperature different from that at which it was calibrated. The calibration curve of the standardized thermoelement is computed for the particular temperature of the cold junction at the time of the experiment. From this curve and the readings obtained from the base metal pyrometer the calibration curve of the latter is constructed. The ordinary approximate shop methods of correcting for the cold junction temperature are compared with the more precise method.

3. *Determination of the Transformation Points of a Specimen of Steel.*—For this experiment a device has been developed that will permit the location of not only the decalescent and incalescent points, but also the points of less marked absorption or evolution of heat.

4. *Calibration of a Resistance Thermometer.*—Both potentiometer and bridge indicators are used. From the indications at three known boiling points is computed the relation between temperature and resistance. From this equation the calibration curve is constructed.

5. *The Direct Calibration of a Pyrometer by Means of a "Black-Body" and a Standardized Thermoelement.*—The Fery lens radiation pyrometer, the Fery mirror radiation pyrometer, the Fery spiral radiation pyrometer, the Thwing radiation pyrometer and the Shore pyroscope are calibrated by a step-by-step direct comparison with a standardized thermoelement.

6. *Calibration of a Le Chatelier Optical Pyrometer.*—From the theory of the instrument and the observation of a "black body" at one known temperature a complete calibration curve is constructed. This is compared with the curve obtained by a step-by-step comparison of the optical pyrometer readings with the thermoelectric pyrometer readings of a "black-body" at a series of temperatures.

7. *Calibration of a Wanner Optical Pyrometer.* — A calibration curve is constructed based on the reading obtained when directed toward a "black-body" at one known temperature, and this curve is compared with the calibration curve obtained from observations on a body at a series of known temperatures.

8. *Calibration of a Holborn-Kurlbaum Optical Pyrometer.*—From the observations on a body at three known temperatures the equation of the calibration curve is computed. The curve obtained from this equation is compared with the calibration curve obtained from a series of known temperatures.

9. *The Determination of the Relation Between the Luminous Intensity and the Temperature of an Incandescent Lamp Filament.*—In this experiment a curve is obtained coördinating the temperature of the filament and the current traversing it, and also a curve coördinating candle power and current. From these two curves the required curve showing the relation between candle power and temperature is constructed.

10. *Calibration of a Fery Absorption Pyrometer.*—From the readings obtained when directed toward a "black-body" at two known temperatures the equation of the calibration curve can be found. The curve obtained by means of this equation is compared with one obtained from observations of a body at a series of known temperatures.

As in the other laboratory courses of the department of physics at Purdue University, before a student begins an experiment in this course he must write an analysis of the experiment which shall include the derivation of all equations used, the method of making the computations and an outline of the laboratory procedure. After completing the required observations he tabulates the data, makes the necessary computations, constructs his curves, and writes the laboratory report.

The analysis, the experiment, the computation and the report are all done under class-room conditions, without book, notes or any other assistance than that which may be given by the supervising instructor. This practice results in efficient preparation on the part of the student and a low laboratory maintenance cost on the part of the department.

A New Diaphragm Pump

The Colorado Iron Works Company of Denver, Col., has brought out a diaphragm pump which is felt to

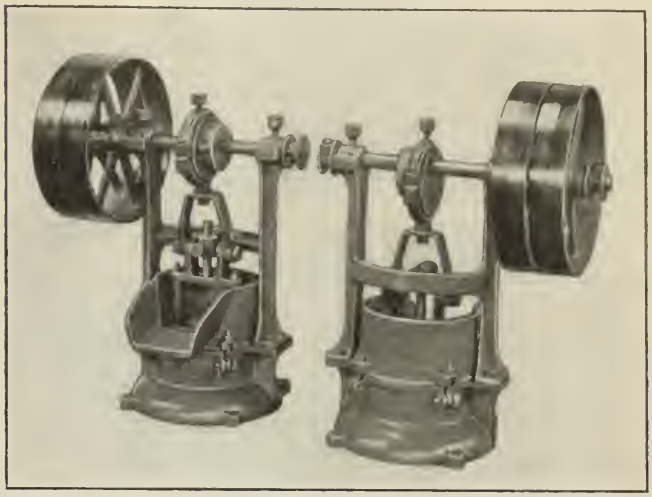


FIG. 1—NEW TYPE OF DIAPHRAGM PUMP

meet the requirements of handling slime in cyanide plants and similar work, and at the same time offers important advantages in the matter of convenience. The pump is illustrated in Figs. 1 and 2.

In ordinary power-driven diaphragm pumps, the power is applied through a rocking motion which causes

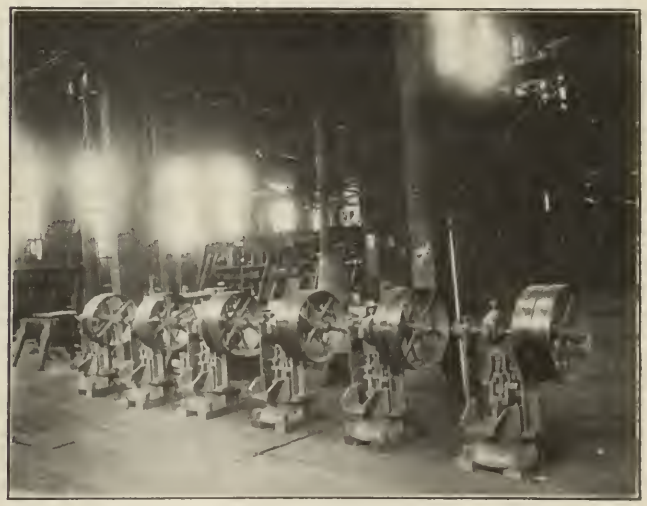


FIG. 2—DIAPHRAGM PUMPS ON ASSEMBLING FLOOR

rapid deterioration and failure of the diaphragm. In the pump under consideration this disadvantage is overcome by the use of an eccentric and cross-head working

in a guide. While this greatly increases the life of the diaphragm, yet to facilitate its replacement without disturbing the driving mechanism, the pitcher spout portion which holds the diaphragm in place can be raised for removal of the ruptured diaphragm and insertion of the new one. Hook bolts are here used to eliminate all possibility of dropping them or their nuts, possibly into a tank full of pulp.

Recognizing the advantage of a pump which will deliver the material at a uniform rate, this one is fitted with adjustable eccentrics such as used on jigs, whereby the length of stroke can be adjusted within a wide range to suit the desired volume, without changing the speed.

The pump is made with 3-in. and 4-in. suction, uses standard diaphragms and can be had with either side or bottom suction. While being a suction pump and consequently subject to limitations as to lift imposed by altitude and the density of pulp, it nevertheless has sufficient lift for most applications, and where it applies it offers probably the most satisfactory means obtainable.

British Producer-Gas and Ammonia-Recovery Plant

London *Engineering* of June 4, 1915, contains an interesting description of the producer-gas and ammonia-recovery plant developed by Mr. Arthur H. Lymn of

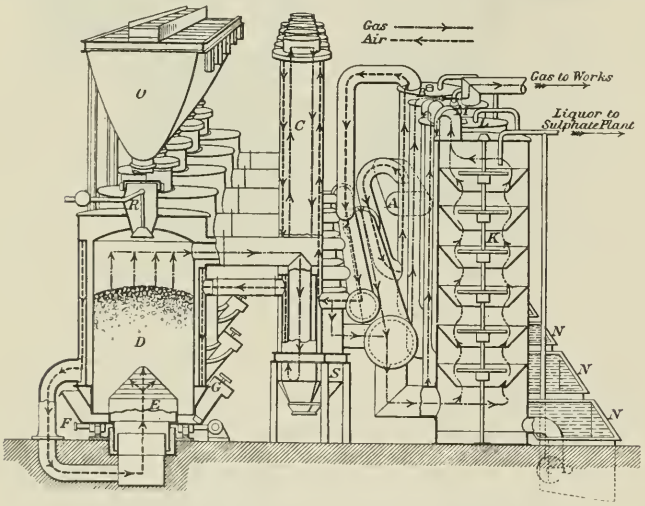


FIG. 1—DIAGRAM OF CYCLE OF OPERATIONS

Sanctuary House, Tothillstreet, Westminster. Although of British origin, the Lymn system has had some of its most important applications in Germany. During the two years immediately preceding the war, contracts for Lymn plants having a total value of about $500,000 were secured in Germany.

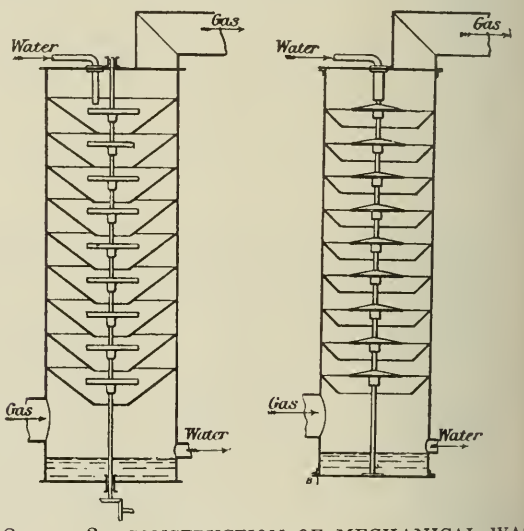
A perspective diagrammatic sketch of a Lymn plant is given in Fig. 1. In a general way it is based upon the Mond process, the essential patents of which have expired. The Lymn apparatus, however, has many features peculiar to itself, and in connection with these various advantages are claimed, as, for instance, low first cost, smallness of space occupied, and simplicity of operation. The plant is automatically regulated, and is capable of using a large range of fuels. It is stated that by-products can be profitably recovered in units as small as 500 horsepower. The special features of the Lymn producer and recovery plant are largely concerned with the ammonia-absorption, gas-washing, gas-cooling and air-saturating arrangements, the common high and bulky towers having been replaced by a novel system of vertical washers, in which the washing of the gas is chiefly brought about by its own momentum.

The cycle of operations, about which there is little novel, will best be followed by reference to Fig. 1, where D is the gas-producer, E the grate and F the water seal. This seal allows ashes to be removed from the grate by the apparatus G without interfering with the working of the producer. This operation is performed automatically or manually, depending on whether the grate is mechanical or non-mechanical. Above the producer there is an overhead fuel banker O, feeding to a charging-hopper R.

In Fig. 1 the heavy dotted lines represent the path of the air, and the dot-and-dash lines the path of the gas. The arrows on these lines indicate the direction of flow at various points. It will be seen that the air and steam blast enters the fuel in the producer through the grate; before dealing with this point in the cycle, however, it will be well to trace back the air stream to its point of origin at the blower A.

The blower is of the Roots, or some such type. The air from the blower first passes through the air-saturating apparatus B, in which it is brought into intimate contact with hot water and becomes saturated with steam. The water is heated during the cooling of the gas at a later point of the cycle. The saturating apparatus B will be described in detail later. From the saturating apparatus the air passes to the superheater C, in which it is superheated by the hot gases from the producer. The air and gases pass through the superheater in opposite directions. From the superheater the air and steam mixture may pass through the jacket of the producer, through the grate, and into the fuel bed. It is further heated in passing round the producer through the jacket.

We may now deal with the path of the gases, which as they leave the producer carry with them the ammonia and other constituents, which are afterwards recovered as by-products. The hot gases first pass to the superheater, where, in heating the stream of air and steam, they part with much of their heat, which is thus



FIGS. 2 AND 3—CONSTRUCTION OF MECHANICAL WASHER AND COOLER

recovered and returned to the producer. From the superheater the gases pass through a dust-separating apparatus S to the ammonia-absorber K. In this absorber the gases are brought into intimate contact with an atomised solution of sulphate of ammonia containing a small excess of sulphuric acid. The acid dissolves the ammonia in the gases, and the solution passing to the bottom of the absorber enters the tanks N. From the absorber the gases pass to the gas-cooler L, which is

an apparatus of the same type as the absorber. Here they are brought into intimate contact with cold water. This gas-cooler works in a cycle with the air-saturator, B, which has already been referred to in connection with the path of the air. The water first passes through the gas-cooler, thus cooling the gas and at the same time itself becoming heated. It then travels to the saturator, and saturating the air, is itself in turn cooled, and is then ready for a further passage through the gas cooler.

By the use of this cycle it is clear that a large amount of heat, which would otherwise be wasted, is recovered from the gas and returned to the producer as steam. On leaving the gas-cooler L, the gases pass to a second cooler M, where they are again brought in contact with cold water. Leaving this they are sufficiently clean and cool for firing boilers or furnaces, but if they are to be entering at the bottom, passes up through the finely-divided spray and is cooled, or, in the case of the absorber, has the ammonia it is carrying dissolved out. This type of mechanical washer or cooler is not novel, but Mr. Lymn is believed to have been the first to apply it to producer-recovery plants. Originally he designed his coolers on traditional lines, but on watching their operation he came to the conclusion that the momentum of the gas was a more important agent in the mechanical mixing than the rotation of the discs. Accordingly, he cut away a considerable part of the collecting cones to give the gas more play, and finally he was able to handle the gas from 90 to 100 tons of coal in a cooler which was traditionally designed to handle the gas from 45 to 50 tons.

This work ultimately led to the type of construction shown in Fig. 3. In this it will be seen that the holes

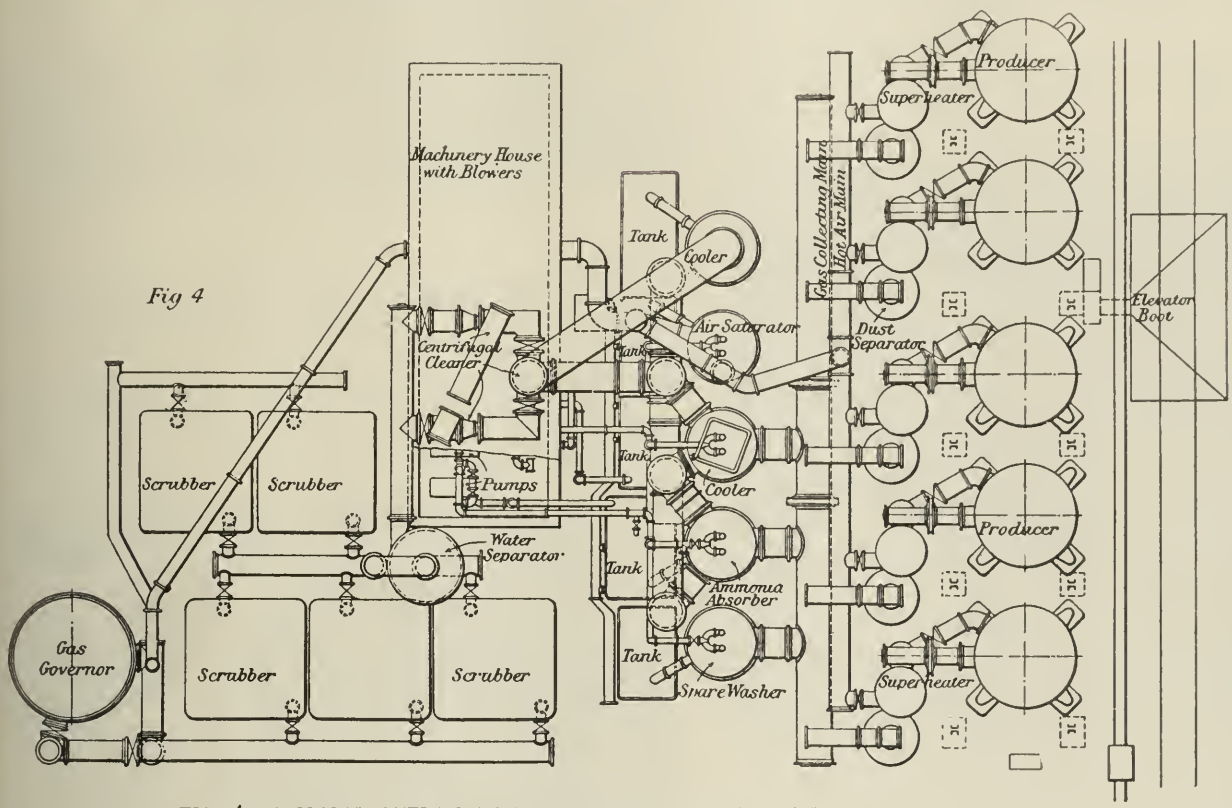


FIG. 4—GENERAL OUTLAY OF PRODUCER-GAS AND AMMONIA-RECOVERY PLANT

sed in gas engines they have still to be treated for he removal of tar. This process is carried out in centrifugal cleaners and dry scrubbers of the usual type. he sulphate of ammonia is recovered by evaporation f the solution collected from the ammonia-absorber by he tanks N. The solution is circulated through these nks and through the absorber until it is very concenated, when but little evaporation is required for ystallizing out the solid salt.

The design of the saturator B, the absorber K, and e gas-coolers L and M undoubtedly forms one of the ost interesting features of this plant. It is indicated some extent in Fig. 1, but may be more clearly exained by reference to Figs. 2 and 3. Referring first Fig. 2, it will be seen that the arrangement consists a vertical cylindrical chamber, containing a series of verted truncated cones. Up to the middle of the amber a shaft runs, carrying a number of discs. The aft is rotated by gearing at the bottom end. The ter enters the cooler at the top, and falling onto the st rotating disc is sprayed onto the surrounding ne. From this it falls onto the next disc, to be rayed to the succeeding cone, and so on. The gas, in the bottom of the cones are of considerably larger diameter than the discs, so that if no gas is passing water entering the top falls straight to the bottom. So important has the effect of the momentum of the gas proved to be in this form of cooler that in the design shown in Fig. 3 it has been found possible to do away with the rotation of the discs altogether, and plants have now been in successful operation for more than two years with fixed discs. The importance of these improvements, which have doubled the capacity of the coolers, and at the same time simplified them, is obvious. The capital outlay is largely reduced and space is saved. Coolers of the type shown in Fig. 3 can be built to deal with gas from 10,000 cu. ft. an hour to 1,300,000 cu. ft. an hour in a single unit. It should, perhaps, be said, as will probably be obvious, that the dimensioning of these coolers is not altogether a simple matter, and that they are designed empirically from data built up from practical experience.

In connection with other parts of the gear it may be said that considerable pains have been taken to apply to these ammonia-recovery plants the mechanical agitation of the fuel and ash zones of the producer, as well

as mechanical ash removal, which have been so widely applied to ordinary gas-producers in Germany. The producer is based on the principle which has been so largely utilized for hot-gas producers, and involves a rotary grate and mechanical ash removal somewhat on the lines introduced by Kerpely of Vienna, and others. Adapting a hot-gas producer for ammonia-recovery conditions, Mr. Lymn has naturally found material modifications necessary, owing to the greatly increased volume of air and steam, the deeper fuel-bed, the necessity for superheating the blast of air and steam, etc. An interesting point in connection with this plant is that it contains no lead parts. Steel is used for the ammonia-absorbing apparatus. In a plant which has been in operation in Germany for four years, and which contains no lead whatever, no corrosion has been found. A plan showing the general lay-out of a Lymn plant is given in Fig. 4. The functions of the various parts will be followed in connection with the sketch of the method of operation we have already given.

Among the various plants in operation in Continental Europe, *Engineering* mentions one belonging to the Badische Anilin und Soda-Fabrik at Ludwigshafen, and another belonging to the German government at Heinitz, and a plant of six producers built for firing steel furnaces at the Barop Steel Works.

In Table I the actual operating results are given for a Lymn plant over two periods of four weeks each.

TABLE I—OPERATING RESULTS OF POWER-GAS PLANT (LYMN SYSTEM), DRIVING LARGE GAS-ENGINES AND FIRING FURNACES

This plant was designed to gasify 45 to 50 tons of coal per 24 hours. It has since been extended, and is now gasifying about 80 tons, and is driving four 1300-hp gas-engine electric sets, and also firing four furnaces. The coal in use is smalls, through a ¾ in. sieve, and ordinary brown-coal briquets. Average price, 12 to 13 marks ($3 to $3.25) per ton.

FIRST PERIOD, BETWEEN NOVEMBER 20 AND DECEMBER 22, 1912 (FOUR WEEKS)

	Total	Average per day of 24 Hours	General Average
Coal consumption of the gas plant	1806 tons	64.6 tons	0.72 kg. per kw-hr.
Power produced (kw-hr.)	1,889,740 kw-hours	.....	2812 kw-hours per hour
Yield of sulphate of ammonia	49.11 tons	1.76 tons	27.1 kg. per ton of coal
Yield of tar (containing water)	189.7 tons	6.78 tons	105 kg. per ton of coal
25 per cent of total gas produced is used for firing furnaces.			

Average heat value of the gases, 1380 calories per cubic meter (155 B.t.u. per cubic foot).
Tar contained in the gas (average), 0.04 gram tar per cubic meter.
The auxiliary machines (excluding blowers) consumed regularly 71 kw.
Including 10 per cent depreciation, the gas costs per kw-hour work out at 0.55 pfennig (0.138 cent).

SECOND PERIOD, BETWEEN JANUARY 27 AND FEBRUARY 23, 1913 (FOUR WEEKS)

	Total	Average per Day of 24 Hours	General Average
Coal consumption of the gas plant	1967 tons	70.2 tons	0.78 kg. per kw-hr.
Power produced (kw-hr.)	1,899,600 kw-hr.	.....	2830 kw-hours per hour
Yield of sulphate of ammonia	54,300 kg.	1.94 tons	27.6 kg. per ton of coal
Yield of tar (containing water)	231,700 kg.	8.27 tons	117 kg. per ton of coal
25 per cent of total gas produced is used for firing furnaces.			

Average heat value of the gases, 1370 calories per cubic meter (154 B.t.u. per cubic foot).
Tar contained in the gas (average), 0.057 gram per cubic meter.
The auxiliary machine (excluding blowers) consumed regularly 78 kw.
Including 10 per cent depreciation, the gas costs per kw-hour work out at 0.56 pfennig (0.14 cent).

NOTES

1. Nitrogen contained in the coal (average), 0.8 per cent.
2. Heating value of the coal, 6000 kg. cal. per kg. (10,400 B.t.u. per lb.).
3. The nitrogen efficiency during these two periods was 70 per cent. It is frequently 75 per cent.

The periods are not specially selected. It will be noted that in spite of the low nitrogen content of the coal and its high price the cost of gas per kilowatt-hour worked out at only 0.14 cent.

There is one point in connection with this branch of industry which deserves considerable attention. The amount of steam generally used by these plants is about 2½ tons for every tone of coal gasified. Of this amounts up to two-fifths, or 1 ton per ton of coal gasified, is recovered from the heat of the gases in a modern plant. This steam is recovered during the gas-cooling and air-saturating cycle. The remainder has to be raised either by means of direct coal-fired boilers or in some other way. Needless to say, the employment of special coal-fired boilers involves a considerable charge on the operating costs of the plant, and the alternative of utilizing waste heat from gas engines, furnaces, etc., to raise such steam offers considerable attractions. In the plant referred to in Table I, which has been in operation for four years, the whole of the steam is raised in this way. There are four boilers, each attached to a 1300-hp gas engine. They raise 2 lb. to 2½ lb. of steam per hoursepower-hour. The steam produced is quite 25 per cent in excess of that required for the gasification of the coal. Corrosion is sometimes mentioned as a difficulty in connection with this form of application, but in Mr. Lymn's opinion the matter is purely one of properly dimensioning the boilers. The plant in question has been in day and night operation for four years without any trouble from this cause. It is stated that this plant was the first in existence absolutely self-contained in the matter of steam supplies.

Exhibits at the San Francisco Exposition

Carborundum Exhibit

Prominent among the exhibits in the Palace of Machinery is the display of The Carborundum Company, Niagara Falls, N. Y. The accompanying illustrations give some idea of the attractiveness of the display,

FIG. 1—CARBORUNDUM EXHIBIT

embodying a grand idea of broad industrial education.

In brief the plan of the exhibit is to show the varied uses to which carborundum products are put, to show the wide variety of materials and products in their crude or unfinished state and after they had been cut, ground or finished with carborundum products. The result has been a wonderful collection gathered from manufacturing plants, not only in this country, but from South America, England, India, New Zealand, Australia and other foreign countries. The collection embraces materials and products ranging from tooth picks to flooring, from flour mill rolls to needles, from steel shafts to watch dials, from semi-precious stones to shrapnel shells and malleable castings, and also includes samples of marble, onyx and granite, pearl, cut

and engraved glass, sueded skins and boots and shoes. In the grinding, shaping and finishing of every piece of the show, carborundum products have played their important part, and in each case the particular carborundum product which did the work is shown.

FIG. 2—CARBORUNDUM FOUNTAIN

To display the hundreds of products, a space of about 1400 square feet was necessary. The materials are shown in full glass show cases (Fig. 1). In the center of the exhibit is a fountain (Fig. 2), built of irregular masses of iridescent carborundum crystals, over which real water plays, splashing into a marble basin, the coping for which was moulded with carborundum wheels. The fountain is twelve feet high and is strikingly beautiful.

Cork Exhibit—Heat-Insulating Materials

Industrial education is also the keynote of the joint display of the Armstrong Cork Company and the Armstrong Cork & Insulation Company of Pittsburgh, Pa.

FIG. 3—HEAT-TREATING FURNACE INSULATED WITH NONPAREIL BRICK. MODEL AT SAN FRANCISCO EXPOSITION

The exhibit is situated at the corner of Sixth Street and Avenue A in the Palace of Manufactures and occupies a space 26 by 40 ft. No attempt whatever was made to have a "big" display. Emphasis rather has been placed on perfection of detail. The pavilion itself reflects this idea.

Entering it from the Sixth Street side, the first thing that attracts the visitor's attention is the display of corks and cork specialties. Here may be seen pieces of "virgin cork," "second stripping bark," and a number of specimens of the third and subsequent strippings (cork being really the outer bark of a species of evergreen oak which flourishes only in the Spanish Peninsula, Southern France and Northern Africa). Some of the sheets are of exceptional size, others of unusual thickness. A cross-section of a cork tree is also on display, showing the dense, heavy wood of the trunk, the thin inner bark—which is the seat of the growing processes, and the thick outer coating of cork.

Attractively arranged in ninety-five glass jars are corks of every kind and description and for any kind of service. In a show case are exhibited an amazing array of cork specialties.

Of greatest interest to our readers, however, will be the exhibit of heat-insulating materials. All of these articles exhibited, except one, are by-products of cork

FIG. 4—MUFFLE FURNACE INSULATED WITH NONPAREIL BRICK. MODEL AT SAN FRANCISCO EXPOSITION

—manufacture either solely, or in part, from cork waste. The one exception is "nonpareil" high-pressure covering for steam lines and other heated surfaces, which is composed of diatomaceous earth (kieselguhr) and asbestos.

The most important of this group of products is nonpareil corkboard, for insulating cold-storage warehouses, ice factories, packing plants, breweries, dairies, creameries, fish freezers, fur storage vaults, refrigerators, etc. The principal steps in this manufacture are shown by suitable specimens, and few visitors are not surprised to learn that the particles of cork waste are held together solely by the natural gum or rosin which is brought out by the manufacturing process.

Of somewhat similar interest is the display of nonpareil cork pipe covering for brine, ammonia and drinking water lines. Some idea of its commercial importance may be gathered from the fact that this product is manufactured in more than 1500 different shapes, sizes and grades.

The exhibit of nonpareil insulating brick, which adjoins that of cork covering, is an unusual demonstra-

tion of how modern science produces new articles by combining two or more substances long well known. These insulating brick—so light that they float on water—are composed of diatomaceous earth mixed with ground cork, molded into brick form and then fired. The cork is burned out entirely, leaving the brick extremely porous in texture and a light terra cotta in color. A series of nine models, complete in every detail, show how the brick are installed in boiler settings, bread baking ovens, heat treating furnaces, hot blast mains, brick kilns, etc., to save fuel. Their remarkable heat-insulating efficiency, moreover, is demonstrated by an electrically-heated furnace, which is maintained constantly at a temperature of 1000° F.

But the most interesting feature of the display of heat insulation is a cross-section of a typical cold storage plant, built to scale and complete in every respect. In this model, which is 7 ft. 4 in. wide and 7 ft. high, the commercial installation and use of the entire line of nonpareil heat insulating materials are effectively demonstrated. For example, the boiler is insulated with miniature nonpareil insulating brick, the steam lines and feed water heater are covered with nonpareil high-pressure covering, the brine and ammonia pipes are covered with nonpareil cork covering, while the brine cooler, ammonia accumulator and fore-cooler are insulated with nonpareil cork lagging. The second, third and fourth stories of the model include an ice freezing tank, ice storage, and meat, butter, fruit and egg storage rooms—all insulated with nonpareil corkboard. Miniature tubs of butter, barrels of fruit, crates of eggs and sides of meat add a finishing touch of reality to the whole structure.

A motor-driven fan a few yards away, which serves to demonstrate the sound, and vibration absorbing value of nonpareil cork machinery isolation is the next thing that usually catches the attention of the visitor. This material is used under fans, motors, pumps, printing presses and other machinery to deaden noise and diminish vibration.

Other exhibits are cork paving brick (a combination of finely ground cork and asphalt), cork tilings for museums, libraries, etc., and the linoleum department, powdered cork being the basic ingredient of linoleum.

Mining Exhibits

The Mines and Metallurgy Departmental Jury of the Panama-Pacific Exhibition has adopted unanimously the following resolution:

"*Resolved*, That the Mines and Metallurgy Group Jury of the International Jury of Awards of the Panama-Pacific International Exposition desires to convey to the administration of the exposition and to the exhibitors in the Mines Department an expression of its high appreciation of the service which has been rendered to the mining industry and of the stimulus which has been given to the wise development of the world's mineral resources by the exhibit in this department. The jury heartily congratulates the chief of the department of mines and metallurgy, Prof. Charles E. van Barneveld, on the great success of the exhibit.

"Taken collectively, the exhibit displays a remarkable development in the method of presenting the mining industry for the general revise and education of the public. This development is not due so much to improvements in the individual methods of display, but rather to the adoption of a new point of view of planning and arranging the exhibit materials as a whole. The fundamental thought running through the entire exhibit is to set forth in a vivid and forceful manner the tremendous utility of our mineral resources. A systematic collection of the ores of the various metals and non-metals forms but the first step in a series of exhibits which demonstrate the basic importance of the mineral industry to civilization. The great variety of products derived from our mineral deposits shows in the most impressive manner the fundamental dependence of our industries upon the mineral supply.

"The results show great achievements in establishing step by step the interdependence of mining and manufacturing, with special emphasis placed on the paramount necessity of safeguarding human life and conserving human energy. The results have greatly increased the popularity of the mining department and have made the building a rendezvous for the public as well as for the specialist.

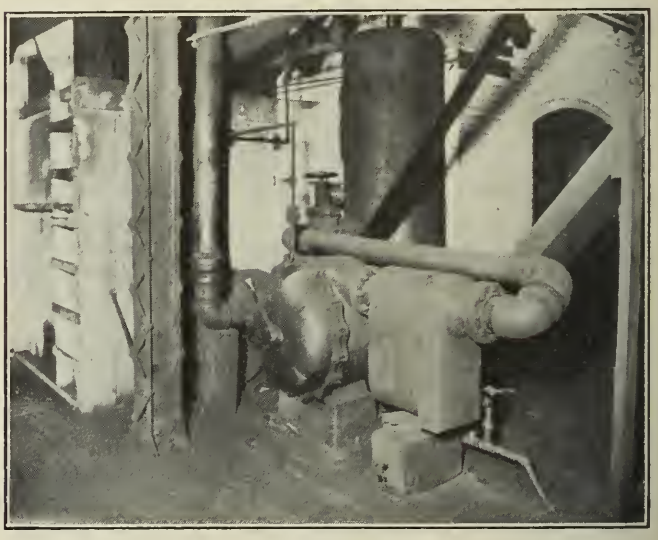
"In general, the mining industry is so clearly depicted as to make this jury cordially urge the visiting public to profit by the educational opportunities offered by this department."

* * *

The International Jury of Awards, Panama-Pacific International Exposition, has voted to give a medal of honor to the publications of the McGraw Publishing Company, Inc., which include METALLURGICAL AND CHEMICAL ENGINEERING. This is the highest award granted a publishing company. The principal basis of the award is the general excellence and superiority of these publications.

Air Compressor

The accompanying illustration shows an illustration of an air compressor at work in the plant of the Nungesser Carbon & Battery Co., of Cleveland, Ohio. This air compressor has been in continuous use for over a year without giving any trouble since or putting the



AIR COMPRESSOR

company to any expense for repairs. It operates over its rated capacity. It is belt driven from a line shaft and takes 43 hp. It operates ten 6-inch air cylinders with 12-inch strokes at 20 pounds pressure per square inch. It also operates other auxiliary air for other purposes around the plant. As its continuous service is all-important for the main purpose for which it is used, since a shut-down would require stopping a considerable portion of the plant, the fact that it is running continuously without adjustment and with its original high efficiency, attaches considerable interest to its design.

The principle of this air compressor which was designed and built by the Nash Engineering Company, of South Norwalk, Conn., is radically different from every other device on the market for compressing air. Its only moving part is a rotor mounted on a shaft, well supported by bearings, and it is arranged to spin freely in an elliptical casing. The pump is filled with water. Power is applied to the end of the shaft, causing the rotor to revolve, which in turn carries the water around with it.

The water, in addition to turning with the rotor, follows the surrounding casing, due to centrifugal force.

As the hub and blades of the rotor are round, and the casing elliptical, it follows that a portion of the water alternately receeds from and reenters the rotor. When the water goes out of the rotor air is drawn in through ports cut in the sides of the casing. When the water is pushed back into the rotor, the water acting as a piston, compresses and delivers the air through the outlet ports.

The water stays at the level of the outlet ports and is used continuously. A small quantity of water is supplied to the compressor to absorb the heat of compression. This water enters at atmospheric pressure and is discharged with the air into a separator, which removes all entrained moisture from the air. The air is thus thoroughly washed of all dust and dirt and contains no oil, which is an advantage where clean air is desired.

There are no valves, gears, connecting rods or moving vanes. The bearings are very large and are relieved of side strains, due to the fact that compression takes place simultaneously on opposite sides of the rotor.

The delivery from these compressors is free from pulsation, therefore no receiver is required. The efficiency is high and the only attention they require is that they are occasionally lubricated and supplied with water.

American-Made Porcelain Ware for Chemical Laboratories

New in the list of manufacturers of high-grade laboratory porcelain ware, but old and well known as a manufacturer of earthenware and porcelain (cooking utensils, etc.), is the Guernsey Earthenware Company of

PLANT OF THE GUERNSEY EARTHENWARE COMPANY

Cambridge, Ohio. It would be wrong, however, to assume that this company went into the manufacture of laboratory porcelain ware as a result of the European war, since, under the direction of its president and general manager, Mr. Charles S. Casey, it had been engaged in experimental work for two years preparing to place upon the American market a laboratory ware in every way equal to that of the imported article.

The clays which go into the makeup of Guernsey ware are both foreign and domestic, and it was the selection of these clays and various tests on various combinations of clays which occupied considerable attention during the experimental period. The result of these experiments has been entirely satisfactory, as all tests have shown that the porcelain is equal to any made in the world, as the company's guarantee reads.

The original pieces manufactured were crucibles, casseroles, evaporating dishes, mortars and pestles, Petri dishes. The demand for these pieces has already reached 2000 per day, and the factory is now being arranged to greatly increase the output both in variety and number, so that it will occupy a space of 200 x 420 feet. Additional ware which will soon be offered comprise beakers, porcelain plates, Rose crucibles, Gooch crucibles, funnels, spatulas, spoons, perforated plates, combustion boats.

The Non-Ferrous Metal Market

The past month has been one of unusual activity in the non-ferrous metal markets. With the exception of tin, which stands in about the same position as a month ago, the metals command higher prices. A good volume of business has been transacted. Lead has experienced a decided rise, the demand being for ammunition purposes and export. Spelter has continued its unprecedented and spectacular rise, and the climax seems to have been reached.

Copper.—Electrolytic copper has risen steadily to 20 cents per pound, New York, due to the development of an active buying movement on the part of manufacturers of brass for ammunition purposes. Lake copper sold by the Calumet & Hecla company has maintained a price of 23 cents, but there is a tendency on the part of consumers to substitute electrolytic for Lake at these prices, and the differential is diminishing.

Tin.—A lull was experienced in this market during the latter part of May, but increased transactions early in June restored a firmer tone. The metal is quoted at about 40 cents, New York.

Lead.—An advance began late in May, due to large inquiry from ammunition makers, and the price was set at 4.30 cents, New York, by the A. S. & R. Co. Later the advances became a matter of daily occurrence and reached nearly 7 cents. A large business was transacted before the market began to decline.

Spelter.—June spelter reached the record price of 25 cents, St. Louis, on June 9, and about the same time the demand began to diminish. The galvanizing trade is practically out of the market at these prices, and other consumers have shown a disposition to withhold for the time being. The fluctuations in price have been rapid and wide, and an accurate quotation is difficult.

Other Metals.—Aluminium has been active and strong, and the price has risen to 27 to 29 cents, New York. Antimony continues strong, with a range in prices from 35 cents for ordinary brands to 48 cents for Cookson's. The latter is largely nominal. Quicksilver has again risen, small lots bringing $100 per flask of 75 lb., and larger orders $85. The price at San Francisco is somewhat lower, ranging from $75 to $85.

Personal

Mr. **George O. Bradley**, consulting mechanical engineer for the Utah Copper Co., has been retained to design and supervise the construction of the 8000-ton Alaska Juneau mill. Mr. Bradley designed the new mill for the Alaska Gastineau company.

Mr. **Sidney Cornell** is now efficiency engineer of the Remington Arms & Ammunition Co. at Bridgeport, Conn.

Mr. **Russell T. Cornell**, engineer of mines, announces the removal of his office to 80 Maiden Lane, New York City. His new quarters adjoin those of Ricketts & Co., Inc., by whom he has been retained as associate mining and consulting engineer. His new association will not affect his status as an independent engineer.

Mr. F. M. De Beers, general manager of the Swenson Evaporator Company, of Chicago, was in New York in June and reported very lively activity in evaporator construction for various new chemical industries.

Mr. J. V. N. Dorr has returned to New York from Denver.

Mr. L. G. Eakins, former assistant manager of the Colorado department of the American Smelting & Refining Co., has been appointed general manager for Colorado, succeeding the late Franklin Guiterman. Mr. Eakins has also been appointed president of the Carbon Coal and Coke Co.

Prof. Albert J. Houle, of the department of mining and metallurgy, Michigan College of Mines, is spending part of the summer in Utah studying metallurgical processes.

Mr. Dorsey A. Lyon, of the Bureau of Mines, has returned to his station at Salt Lake City following a visit to the Joplin zinc and lead districts.

Mr. Ferdinand McCann is in charge of the erection of new milling plant at La Cotabambas Auraria mine, Peru.

Mr. Benjamin Magnus is returning to America and expects to be in New York by September, where his headquarters will be in care of H. M. Toch, 320 Fifth Avenue, New York City. Mr. Magnus went to Australia in 1907 to build the Electrolytic Refining and Smelting Company's Works at Port Kembla, N. S. W., for the refining of copper produced by Australian mines. In 1912 he became general manager of the Mount Morgan Gold Mining Co., Ltd., and designed the new smelter works and concentrator and reorganized the company's business generally. He also acted as consulting engineer to the Electrolytic Refining and Smelting Co., Ltd.

Mr. H. T. Matthew has been appointed Pacific Coast representative of the Society for Electrical Development. Mr. Matthew has with him the best wishes of many readers and friends of this journal of which he was the business manager for six years when it was still called Electrochemical & Metallurgical Industry.

Professor Arthur A. Noyes, of the Massachusetts Institute of Technology, is the recipient of the Willard Gibbs medal for 1915, awarded by the Chicago section of the American Chemical Society.

Mr. O. B. Perry, general manager for the Yukon Gold Co., has left New York on a trip of inspection of the company's properties in California and Alaska.

Mr. Charles H. Schmalz has been appointed manager of the Billings Foundry & Mfg. Co., of Billings, Mont. For the past six years Mr. Schmalz was master mechanic for the Anaconda Copper Mining Co., Boston, and Montana Reduction Department, Great Falls, Montana.

Mr. Arthur Putnam Scott, formerly with the Dominion Iron & Steel Company of Sydney, N. S., and with the General Electric Company, is now chief metallurgist of the Snyder Electric Furnace Company of Chicago. Mr. Scott contributed to this journal a most interesting article on "hard spots" (July and August, 1908, vol. VI, pages 281 and 323).

Mr. G. F. Streich is in charge of the zinc smelting plant at Bruce, Kansas, leased and operated by the Cherokee Zinc Co.

Mr. W. C. Tharp has been appointed district manager in charge of the Pittsburgh office of the Hoskins Mfg. Co. Mr. Tharp has been associated with the Republic Iron & Steel Company, the Scientific Materials Company, and the Metallurgical Testing Laboratory of Pittsburgh.

Mr. A. E. Wiggin has been appointed superintendent of concentration for the Anaconda Copper Mining Co., and will have charge of concentrating operations in Montana. Mr. Ralph Hayden has been appointed superintendent of the regrinding and flotation plants at the Washoe works, and will also have charge of the new slime plant on its completion. Mr. W. A. Estabrook retains the position of superintendent of the concentrator at Anaconda. Mr. C. R. Wraith has relieved Mr. E. S. Bardwell at the company's exhibit at the Exposition.

Obituary

Thomas Dyson West, iron foundry expert, died in June as a result of the injuries received when run down by an automobile near his home in Cleveland, Ohio. Mr. West was widely known in this country and abroad for his untiring efforts for the foundry industry, while his organizing and developing of the American Anti-Accident Society and the Sane Fourth Movement show the broad field which he endeavored to cover. Thomas D. West was born in Manchester, England, on August 31, 1851, his mother being a niece of Michael Faraday. He was brought to the United States by his parents when six months of age. At twelve years he began to work in a foundry and remained true to the foundry industry ever since. Mainly self-educated, he was from 1887 to 1909 organizer, vice-president, and general manager of the Thomas D. West Foundry Co., now Valley Mould & Iron Company, Sharpsville, Pa. In 1907 he organized the West Steel Casting Company of Cleveland, Ohio, of which he was chairman of the board and managing director at the time of his death. By his research work and by his writings he gained wide recognition as a foundry metallurgist. He was the originator of the use of standardized drillings, adopted by the U. S. Bureau of Standards in 1905. In 1905-6 he was president of the American Foundrymen's Association. He also was a member of the American Society of Mechanical Engineers, the American Society for Testing Materials, the American Association for the Advancement of Science, and the Cleveland Engineering Society. He was a prolific author. Of his books, "American Foundry Practice," which has reached its eleventh edition, is probably best known. He is survived by his widow, Mrs. Clara West, and three children, Dr. Thomas J. West of Honolulu, Mr. Ralph H. West, president of the West Steel Casting Company of Cleveland, and Mrs. William E. Ward of Cleveland.

Alain de Pierrefeu, engineer in charge of the metallurgical and industrial division of tests of the Illinois Steel Company, South Chicago, was killed in May in France. Educated in France and in the Lawrence Scientific School he entered service in the mills of the steel company in the lowest position seven years ago. He worked up through the laboratory section until he had charge of testing all kinds of special steel and various treatments of structural steel. He was an officer of the Seventeenth Infantry and left for the war last October. Letters to Langdon Pearse state that he was wounded about two months ago and had been obliged to leave the trenches on account of eye strain. His wife, a daughter of William Tudor, of Boston, is in Red Cross work abroad but the four children are with the grandparents in Boston.

Erratum.—The communication by Mr. Carlton G. Lutts on rapid analysis of bearing metals and high-copper content alloys, published in the June issue, page 346, contains a misprint in the second column under copper (B), where $Na_2S_2O_3$ (sodium thiosulphate) should read Na_2SO_3 (sodium sulphite).

Newspaper Chemistry

There was a man in our town
And he was wondrous wise,
He cracked petroleum odds and ends
With vim and enterprise.

He first cracked off some gasoline
And then some heavier bodies
Until he made a full, long list
Of Coal Oil Johnny's toddies.

And when he saw what he had done
With all his might and main
He curled them up, and into rings
He twisted every chain.

'Twas then the newspapers began—
And that's where chemistry
Can work all sorts of miracles
Most expeditiously.

The papers first took up benzol,
And, quoting Edison,
They made phenol by synthesis,
And dyestuffs, every one:

Alizarine and indigo
And all the coal-tar group
For dyes and photochemistry
They made in one fell swoop.

Then starting out with toluol
They made explosive stuffs
To smash the foes of Uncle Sam
In detonating puffs.

They made a neo-gasoline
For motor trucks and cars
So cheap that poor old Standard Oil
Was jolted full of jars.

And with this neo-gasoline
They ploughed the fertile fields,
And then, by using radium
They multiplied the yields.

Of wheat, potatoes, millet, corn
And rye and peas and beef;
They banished want and poverty
And hunger, past belief.

I wish I were a chemist of
The journalistic kind!
I'd take and go to work and make
A contract, drawn and signed

To furnish everything there is
And set the world agog;
And do it just as easy as
A-rollin' off a log.

—"E. H." in *The Percolator* of the New York Chemists' Club.

The spectroscopic analysis of steel has been investigated by the Bureau of Standards, at the request of the steel industry. It has been possible to show the presence of appreciable amounts of molybdenum, cobalt and vanadium in steels supposed to be free from these elements. No sample of iron has been found free from magnesium or copper. Silicon was not detected in electrolytic iron that had not been fused.

National Exposition of Chemical Industries

The arrangements of the National Exposition of Chemical Industries, to be held in the New Grand Central Palace, New York City, during the week of Sept. 20 to 25, 1915, are progressing very favorably. Almost one-half of the available space of the main floor has already been reserved by prospective exhibitors.

An auditorium will be provided with arrangements for slide pictures and moving pictures for special lectures by invited prominent speakers. In the evening this auditorium is to be used for meetings of the different chemical societies. The date of the meeting of the New York Section of the American Electrochemical Society has already been fixed for Tuesday, Sept. 21. Other evenings are to be reserved for the New York Section, as well as for the Industrial Section of the American Chemical Society, and for the American Institute of Chemical Engineers and for the New York Section of the Society of Chemical Industry.

The Bureau of Foreign and Domestic Commerce of the Department of Commerce, Washington, D. C., has expressed its hearty sympathy with the Exposition and is expected to arrange a noteworthy instructive exhibit in conjunction with the Geological Survey, the Bureau of Mines, the Bureau of Soils, the Forest Service, and other government bureaus.

The Exposition is being organized by Messrs. Charles F. Roth and Adriaan Nagelvoort, with offices at the New Grand Central Palace, Forty-sixth Street and Lexington Avenue, New York (telephone 6990 Murray Hill), with the co-operation of the International Exposition Company.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Anodes

226,616, April 20, 1880, Jacob Kleinhans, of New York, N. Y.

Relates to anodes for electroplating and describes shaping the anode with an oppositely bent hook at each end, so that a greater or less number of such anodes may be hooked together to increase or decrease the size of anode immersed in the electrolyte.

330,247, November 10, 1885, Henry Liepmann, of London, County of Middlesex, England.

Relates to anodes for electroplating and consists of a bundle of carbon rods, each having copper-plated ends, the assembled bundle being then copper-plated over the ends, or united by cast metal which enters the interstices between the rods. Instead of copper-plating, or cast metal caps, a plastic carbonaceous paste may be used to unite the rods, the paste then being carbonized, forming a solid composite carbon block. The compound electrodes thus made may be mounted between disks, forming a rotary drum for use in electrolytic apparatus.

450,105, April 7, 1891, Ernest Arthur LeSueur, of Ottawa, Canada, assignor of one-half to Charles N. Waite, of Newton, Massachusetts.

Relates to anodes for electrolytic cells, the anode consisting of a number of irregularly shaped pieces of gas-retort carbon, cut to an equal length, all united at one end by immersing in a shallow layer of molten lead, the lead on cooling gripping the several pieces of carbon and forming an anode having an extensive surface, and good electrical contact with each piece.

482,724, September 20, 1892, Thomas Craney, of Bay City, Michigan.

Relates to anodes for electrolytic cells, such as are used in the decomposition of sodium chlorid solutions. The anode consists of a nest of truncated cone-shaped tubular earthenware bodies, or the like, each having side projections by which they are supported upon and within each other, and leaving cylindrical spaces between each cone. The nest of cones is filled with lumps of conducting carbon, the cylindrical spaces also being filled with the same material and leaving the horizontal annular edge exposed to the electrolyte. Instead of separate cones, an earthenware tube with a perforated wall may be used. Instead of using lumps of carbon, a solid block of carbon may be used in the cones or tube, the spaces between the cones being filled with lumps of carbon which contact with the solid block. The cones may also be filled with a carbonizable mass of carbon and binder, and then baked to carbonize the binder.

508,091, November 7, 1893, Elisha Barton Cutten, of New York, N. Y.

Relates to contacts in anodes for batteries, and for electrolysis, and consists in cutting a tapered hole in the end of a rod or block of gas carbon, saturating the carbon surrounding the hole with paraffin, saturating a tapered carbon plug just fitting the hole, and having a projecting outer end, with paraffin, and then driving the plug tightly into the hole in the rod of carbon. A conducting wire is secured to the projecting end of the plug. It contains a reference to another application which is probably patent No. 510,899.

510,899, December 19, 1893, Elisha Barton Cutten, of New York, N. Y.

Relates to anodes for electrolytic cells, and refers to his copending application which became patent No. 508,091. The patent describes a method of testing the joints for resistance by passing a rather strong current through the electrode and measuring the fall of potential by a voltmeter. The joints are adjusted until all show the same fall of potential with the same current.

510,901, December 19, 1893, Elisha Barton Cutten, of New York, N. Y.

Relates to electrodes for voltaic cells and anodes for electrolytic cells, and refers to his copending application which became patent No. 508,091. The carbon electrode is secured to a glass cover by melting glass fragments or pouring molten glass around the joint between the electrode and cover, on the under side, or by melting the glass cover itself by a blow-pipe flame. The molten glass flows into the pores and cavities in the carbon, welding it to the cover, forming a gas-proof joint, and serving to suspend the carbon. Electrical connection is made with the electrode by a tapered carbon plug, as described in his earlier patent.

510,902, December 19, 1893, Elisha Barton Cutten, of New York, N. Y.

Relates to electrodes for voltaic cells and to anodes for electrolytic cells, and refers to his copending application which became patent No. 508,091. It describes securing the electrode to a stoneware cover by fusing glass fragments around the joint between the carbon and the underside of the cover, forming a gas-tight joint, and serving to suspend the electrode. Electrical contact is made with the electrode by means of a tapered carbon plug, as described in his earlier patent.

546,328, September 17, 1895, Carl Hoepfner, of Giessen, Germany.

Relates to an anode having a surface containing at least 10 per cent of silicon, which may consist of ferrosilicon or of pure silicon. The ferrosilicon may be formed by mixing iron and silicon powders with paraffin, the patent not stating how the alloying is effected. It states that the ferrosilicon may be deposited electrolytically. Or a solid electrode may be made in any suitable shape by casting ferrosilicon. The patent further states that pure silicon may be deposited upon an iron or nickel anode.

Book Reviews

Welding. Theory, Practice, Apparatus and Tests. By **Richard N. Hart,** B.S. Second edition, octavo, 210 pages, 127 illustrations; price, $2.50 net. New York and London: McGraw-Hill Book Company.

The practical art is advancing so rapidly that revision was made necessary by the great advances made, especially in arc-welding and oxy-acetylene systems. The divisions of the subject are ordinary welding, electric welding, hot-flame welding (autogenous welding), thermit welding and miscellaneous methods. It is a very satisfactory presentation of a most interesting and useful art.

Ferromangan als Desoxydationsmittel. von W. Rodenhauser. 15 x 23 cm., 127 pages, 49 illustrations. Price 7 marks (retail price in New York $2.35). Leipzig: Oskar Leiner.

Engineer Rodenhauser is well known to steel metallurgists for his work on the Roechling-Rodenhauser induction furnace. This timely book (dedicated to Mr. Roechling) is concerned principally with the latest improvement in manufacturing steel—the addition of molten ferromanganese. It describes the properties and function of ferromanganese, the various means for melting it, and the advantages resulting from adding it melted to the steel. The melting is described in detail as carried on in Rombach, Keller, Girod, Heroult, Nathusius and Roechling-Rodenhauser furnaces. We are sorry to see the Rennerfelt furnace omitted, for a good description of its usefulness for this very purpose was published by the Iron and Steel Institute last year. Notwithstanding this omission, it is a book which every steel maker ought to read.

Principes et Applications de L'Electrochimie. By O. **Dony-Henault, H. Gall** and **Ph.-A. Guye.** Large octavo, xxii + 686 pages, 183 illustrations; price 30 francs, in New York $6.00. Paris and Liége. Librarie Polytechnique, Ch. Beranger.

A splendid volume, containing treatises on the fundamental laws of electrochemistry by O. Dony-Hénault, the synthesis of nitric acid by Ph.-A. Guye, and the other applications of electrochemistry by O. Dony-Hénault and H. Gall. And yet, such is the present great extent of applied electrochemistry that each of the subjects must be spoken of as "briefly considered."

Mirabile dictu, here is a French book with a good analytical table of contents in front and satisfactory indexes of authors and subject matter at the back. What further proof could be needed that it is the best book in its field in the French language?

I Processi Termoelettrici della Siderurgia Moderna: Forni Elettrici. By Ing. **C. F. Bonini.** 15 x 23 cm., 607 pages, 174 illustrations. Price $12.50 lire. Milan: Ulrico Hoepli.

A beautifully printed and well-illustrated treatise on the electric furnaces used in the metallurgy of iron. Part I, in thirteen chapters (318 pages), deals with the principles of construction and operation of electric furnaces in general; it is well written. Part II, in five chapters (105 pages), treats of the direct production of steel from iron ore and the refining of steel; this part is not so thoroughly handled. Part III, in six chapters (170 pages), concerns the production of cast iron and ferro-alloys; it is quite satisfactory.

Any engineer reading Italian and interested in electro-metallurgy or electric furnaces will find it a useful book.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIII NEW YORK, AUGUST, 1915 No. 8

PUBLISHED MONTHLY BY THE
McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer.
239 West 39th Street, New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Colo.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for August, 1915

EDITORIAL:
Coming Exposition of Chemical Industries 465
Bessemer and Open-Hearth Steel 465
Patent Office Procedure 466
Engineering or Legal English? 466
The Steel Industry and the War 466
READERS' VIEWS AND COMMENTS:
Needed Changes in the Patent System. By an Engineer .. 468
A Modified Iron-Carbon Diagram. By Edwin A. Sperry .. 469
Western Metallurgical Field 471
The Iron and Steel Market 473
The Non-Ferrous Metal Market 474
Production of Radium by the Bureau of Mines 474
Columbia University Establishes a Separate Department of Chemical Engineering 475
Co-operation in Chemical Export Trade with South America .. 476
Possibility of Extra Session of Congress and the Tariff 476
Cyanidation of Low-Grade Sulphide Ores in Colorado II. By H. C. Parmelee 477
The Effect of High Ignition Voltages on the Accuracy of Bomb Calorimeter Determinations. By Edward J. Dittus 480
The Potash Situation. By Samuel H. Dolbear 481
Possible Applications of Oxygen in Metallurgy. By J. E. Johnson, Jr. 483
Vacuum Pans. By E. W. Kerr 485
Vanadium from Oxide to Steel. By Warren F. Bleecker and Walter L. Morrison 492
American Electrochemical Society 494
American Chemical Society 494
Blast-Furnace Plant Auxiliaries and General Arrangement. By J. E. Johnson, Jr. 495
Faraday Society Meeting Report 499
Metallurgical and Chemical Engineering in Great Britain 502
Recent Chemical and Metallurgical Patents 504
Synopsis of Recent Chemical and Metallurgical Literature .. 506
Low-Pressure Oil-Burning Metallurgical Furnaces 510
Calibration Curve for Horizontal Cylindrical Tanks 511
Titanium-Aluminum Bronze Castings. By W. M. Corse 511
Centrifugal Pump for Thick Liquors 512
A New Assay Balance 512
Pan-Americanism 513
The Feasibility of Continuous Causticizing 514
Gas Blowing Engines at the Steelton Plant of the Pennsylvania Steel Company 516
Army and Navy Officers Go to Private Plants 519
Obituary 519
Technical Section of American Paper & Pulp Association 520
Personal 520
Book Review 520

The Coming Exposition of Chemical Industries

The curious individual who said that an exposition of chemical industries was a self-contradictory conception because chemical industries were secretive by nature, will find himself hopelessly behind the times when the National Exposition of Chemical Industries opens in New York City on Sept. 20. The commercial success of the exposition seems assured by the generous response of the industry and reversely great benefit can accrue from the exposition to the industry. As the exposition is primarily technical, it is an excellent idea to facilitate and insure the presence of chemists and engineers by arranging meetings of the various chemical societies in connection with the exhibition. In presenting in visible form—and wherever possible, in form of working models—the latest advances in machinery design, construction, and operation, the exposition can fulfill a distinct function of its own. It should be suggestive and encourage exchange of critical ideas and prove another connecting link between various classes of chemists and engineers.

More indirect, though by no means negligible will be the effect of the exposition on the industry by reason of the very fact that the general public will be largely attracted. To procure public recognition for chemistry, the public must be made to realize what chemistry is. No amount of lecturing will do this so well as a direct appeal to the senses. Chemical industry must be visualized by exhibits, working models, moving pictures. This is what the exposition will do. And the logical consequence will be a storage of appreciative good will that must be of immense value in future for the industry not only in connection with financial investments in the industry, but in connection with tariff and other legislation.

Bessemer and Open-Hearth Steel

Despite the astonishing increase in open-hearth steel making capacity in recent years, and a slight decrease in Bessemer steel making capacity, due to the abandonment of at least one large plant and the adaptation of some Bessemer blowing capacity to the duplex process, there is to-day what is described in steel market parlance as a "scarcity" of open-hearth steel. One can purchase Bessemer billets or sheet bars at a lower price than open-hearth billets or sheet bars. Buyers of finished steel who have exhibited a preference for open-hearth steel are in many cases being asked whether a substitution of Bessemer will be permitted. The trade reports state that practically the entire open-hearth capacity is in operation, but only 70 or 75 per cent of the Bessemer.

Sellers of steel insist that in many cases the prefer-

ence buyers express for open-hearth steel is not founded upon adequate knowledge, and that indeed there are numerous buyers who "would never know the difference" if Bessemer steel were substituted for open-hearth. Some sellers of steel actually wax impatient over the attitude of buyers in this connection, but it is in point to observe that in a measure the seller is himself responsible for the condition which now disturbs him. In periods of market dullness the seller who has both Bessemer and open-hearth steel to offer is quite prone to put the open-hearth in the front, thus fostering a habit on the part of the buyer to take open-hearth steel. The position of the seller at such a time has, perhaps, not been entirely altruistic. While we would not undertake to make an authoritative comparison, plant for plant, between the cost of making Bessemer and open-hearth steel respectively, it is a fact attested by the experience of numerous buyers that in the recent period of market stagnation they were able to buy open-hearth billets and sheet bars at a slightly lower average price than Bessemer steel of the same description, and the experience suggests that the maker who conducted both operations found the open-hearth process the cheaper. It may be unfortunate from the seller's standpoint that the buyer will not change his habits to suit the circumstances, but the preference expressed for open-hearth steel can hardly be described as a case of pure pig-headedness on the part of a buyer who would experience difficulty in distinguishing the one class of steel from the other. It can hardly be doubted that Bessemer steel could properly be used more widely than it is. In most cases of employment of merchant bars, pipe and wire no distinction is made, or could be made, by the ultimate consumer.

Patent Office Procedure

Elsewhere in this issue we publish a concise statement on United States patent procedure, viewed from the standpoint of a metallurgical engineer who wishes to remain anonymous though his name is well known from his connection with one of the most celebrated metallurgical patent suits of recent times. The statement is not only critical but constructive. Without committing this journal to every proposal made in the statement we may say that it presents admirably various phases of the situation that are well worthy of serious consideration. In the development of our patent law and practice the original object has been almost defeated. Our patent system was devised to foster the inventive genius; to give equal opportunity to all without regard to material wealth; to protect intellectual property among poor and rich alike.

Unfortunately our patent practice does not vest in the Patent Office the right or duty to pass finally on the validity of a patent when that validity is challenged after the patent is issued. That duty is left to our courts which, incidentally, are ill adapted to the work. The result is that an advantage is given to those who have the power of wealth to prosecute suits, while those less favored in this regard may find their rights abridged. Finally, the whole industry suffers from the uncertainty of the outcome; progress is delayed and the public grows restless under a system which obviously works injustice.

The idea of publishing applications for patents so that all who believe their rights would be abridged by the granting of such patents may challenge their issue is a procedure that has simplified matters in the German Patent Office. If a challenge is offered, it need require only a brief hearing or a demonstration to enable the officials to decide whether the application shall be granted or denied. Such would be the function of the Patent Court suggested by our contributor.

The United States is prodigal in granting patent monopolies. Issued at the rate of about 100,000 per year at a cost for "maintenance and operation" of something like $25 per issue, it is obvious that a wholly inadequate sum is spent to enable the Patent Office to discharge its full duty to the public. Many of the patents granted are inconsequential, and others are in the nature of improvements that would naturally occur to the active mind of anyone engaged in a given line of industry. And yet each is a monopoly that can be made the basis of an injunction to restrain the holder of a like monopoly from exercising the presumptive rights which he obtained from the same source.

With the subject of patent practice receiving so much attention at the hands of competent and experienced thinkers, and with the public conscience quickened to the necessity of establishing conditions under which business and industry can develop normally and unhampered, the time should not be far distant when reform will be accomplished.

Engineering or Legal English?

From a power contract drawn by one of the large power companies at Niagara Falls:

> "The word 'furnish,' when used in this agreement in reference to electric energy, is to be understood to mean readiness and ability . . . to furnish . . . electric energy at the agreed rate."

The Steel Industry and the War

The steel industry of the United States is now almost fully employed. Reports are that substantially all the open-hearth capacity is engaged, and 70 to 75 per cent of the Bessemer capacity, making an average for the industry of not far from 90 per cent. The condition is in striking contrast with that obtaining last December, when operations reached a particularly and unprecedentedly low ebb, at not more than about 35 per cent of capacity.

There is a disposition in some quarters to attribute the present steel-making activity, or at least a great part of it, to demand occasioned by the European war. Such a belief will hardly bear close investigation. It must be recognized, in the first place, that the breaking out of the war caused a great decrease in industrial activity in the United States, while as conditions became better understood there was a reaction. A part of the demand for steel that has been experienced since

Jan. 1 represents simply demand that ought to have been expressed in the closing months of 1914. The fact is worthy of consideration in this connection that an improvement in the steel market occurred in June and July, 1914, and that at the time many reputable observers expressed strong hopes that the improvement then noted represented the beginning of a general movement toward real prosperity. The breaking out of the war suddenly arrested this improvement, but it does not follow that the movement could not be resumed at a later time.

A great deal of the present demand for steel can be traced to ordinary domestic consumers. Freight car orders definitely placed after the war started, and up to the beginning of last May, made a total of only 15,000. In the past three months railroads in the United States have placed orders for about 35,000 freight cars, representing a rate seven times as great. In the three months the French and Russian governments have placed orders in the United States for 21,000 cars. These may be regarded as war orders, but they represent only 30 per cent of the total freight-car buying since the war started. As another illustration of domestic demand it may be noted that while the American motor-car industry has been stimulated by war orders, it is well known that the deliveries of cars to domestic buyers during the season just ended have broken all records, and the automobile industry is entering a new season in expectation of a still larger demand. The export demand may be important, but the domestic demand is in itself making an excellent record. As another illustration it may be mentioned that in April and May, as the agricultural implement industry reached the close of its regular manufacturing season, it was found that the production had been less than it should have been. There was a speeding up at the last moment, and the intention is to make a much larger output in the season now being entered upon. The case of the agricultural implement trade is of particular interest, because it has suffered very seriously in the export direction, the exports in the last fiscal year having been less than one-third as heavy as in the preceding fiscal year.

Illustrations of this sort could be multiplied, showing in detail that the domestic demand for steel has very materially increased. The export movement it is necessary to discuss under two heads, the exports to belligerents and the exports to neutrals. The exports to belligerents, again, must be subdivided into two classes, material required for war purposes, and material required because former sources of supply are shut off. British imports of blooms, billets, sheet bars and wire rods from the United States, according to the June returns of the Board of Trade, are at the rate of over 650,000 tons a year. In chief part this movement represents the shutting off of imports hitherto drawn from Belgium and Germany, but the total imports are somewhat larger than they were a year ago. There are other exports of this character to belligerents, including wire rods to France, nails to both England and France, and scrap and pig iron to Italy.

Of the exports of regular steel-mill products to belligerents only a relatively small proportion can be distinguished as intended for war purposes. By far the largest items are steel bars for the manufacture of shells, and barb wire. In May we exported of the former 37,260 tons and of the latter 18,182 tons, and some portion at least of the tonnage went to neutral countries, but even the total tonnage represents but a trifle more than 2 per cent of our steel-making capacity. As to the steel involved in shells which are manufactured in this country and then exported there are no statistics, but it is evident that the tonnage cannot be more than a very few per cent of our total steel output.

The war would throw a very large tonnage of steel demand from neutral countries to the United States, if the demand existed, but unfortunately no large demand has thus far developed. During three or four years prior to the war the combined exports of the great iron and steel exporting countries, Germany, England, the United States, and Belgium, named in the order of their importance, and excluding exports to each other, averaged very nearly if not quite 10,000,000 tons a year. The only exporting countries now are England and the United States. The British exports to neutral and non-producing countries are now at the rate of about 2,500,000 tons a year, while the similar exports of the United States may be estimated at not more than 1,500,000 tons, making total exports to neutral and non-producing countries of not to exceed 4,000,000 tons, when formerly there was demand for 10,000,000 tons. It must now be mentioned that we include in the British exports just mentioned the exports to India and British colonies, and these exports really amount to fully one-half of the total. There is reason to believe that if the demand increases over the rate of 4,000,000 tons the lion's share of the increase will fall to the United States, since Great Britain does not seem to be in position to accept more business. That is for the future, but there are much greater prospects of our export trade increasing in this direction than of its increasing in the matter of war material. The possible demand from neutral countries covers practically all classes of steel products, while the demand from the belligerents is confined largely to relatively few commodities.

While only rough estimates can be made, it would appear that while our steel exports to neutral countries are at the rate of about 1,500,000 tons a year, our exports to the belligerents of steel in all forms, including that used in the manufacture of shells, motor trucks, railroad rolling stock, etc., do not exceed 2,000,000 tons, or possibly 2,500,000 tons at the very outside. Inasmuch as the present finished steel capacity is in the neighborhood of 27,000,000 or 28,000,000 tons a year, our actual production being at the rate of nearly 25,000,000 tons a year, it is evident that our total steel exports, even including the exports to neutral countries, do not account for any very large part of the present manufacturing activity. The actual consumption of steel in the United States is by far the chief cause of the steel trade's prosperity.

Readers' Views and Comments

Needed Changes in the Patent System

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The experience of our nation with business monopolies has been such as to lead us to place, through our legislative bodies, certain restraints upon the forms and operation of monopolistic enterprises. While we have been following out this policy, endeavoring to re-establish the conditions under which business can have its most normal development, we have overlooked the fact that our Government is annually, through the machinery of the Patent Office, creating thousands of ill-defined monopolies over which no control is retained by the Government, and which are so created that they are in many instances a decided handicap to the development of industry.

The fundamental assumption upon which patents are issued is that the granting of a temporary monopoly in the control of an improved process or apparatus will stimulate the work of invention and the development of new processes and forms of apparatus by making it possible for the inventor to get an adequate profit through the temporary monopoly of his invention, and that the public will profit by this system through the increase in improved processes and apparatus, and the final free use of the same as divulged in the Letters Patent which are granted to the inventor.

NATURAL EVOLUTION OF ARTS AND INDUSTRIES

The development of any art or industry is a gradual evolution, each step of which is made possible by work which has been done before, and each step, in advance of which is, to a considerable extent a natural evolution of what has preceded it. Innumerable instances of practically simultaneous inventions of processes or apparatus, and of practically simultaneous discovery of scientific truths, have demonstrated that many, if not most, of the advances in industry and science would be made by one individual if not by another, because the development of the art or science has brought it to such a state that the next steps to be taken are so much a matter of necessity that they will be taken by any one of a number of those who are confronted with a problem.

It has been a commonly accepted belief that invention partakes somewhat of the nature of inspiration; but a study of the history of the development of any of our arts will show that a great part of the steps forward which have been made, have been the logical result of that which has been done before, and have not involved any high degree of inventive ingenuity or any long period of research. There are, however, many new processes and forms of apparatus which are the result of the application of highly developed inventive capacity to the solution of difficult problems through long and expensive periods of research work.

A patent is a monopoly granted in derogation of one of the most fundamental and valuable rights of mankind, the right of each individual to use for his own profit all of the information which he may possess. This right is of such vast importance that if it is abridged the greatest care should be used to protect, not only the inventor whose work is to be stimulated by the patent system, but the rights of the public, which are definitely restricted by every patent which is granted.

The law, as now enacted and administered, places unnecessary obstacles in the way of the development of industry, as the Patent Office, the chief function of which is to determine whether or not inventors are entitled to patents for their alleged inventions, does not finally determine that matter. A United States patent is not considered to have any established validity until it has been made the subject of litigation which has passed through all of our courts up to the highest tribunal of the land. No technical expert nor legal adviser nor body of experts or advisers can foretell what the courts will consider a patent to cover; or whether or not, on being made a matter of contest, a patent will be held to be valid. To determine the scope of a patent, and whether or not it is valid, requires a contest extending through several years' time and involving enormous expenses. Thomas A. Edison is credited with the statement that an American patent is nothing more than an introduction to the United States Supreme Court. This is practically true, and anyone who has had occasion to be introduced to that exclusive body will realize that the introduction involves a degree of expense which cannot be borne by the type of men who actually advance industry by their inventions.

The effect of this method of dealing with patents is to greatly discourage inventors; to seriously handicap or debar those who have inventive capacity from its profitable employment; to delay the adoption of inventions of proven merit, and to generally and unnecessarily interfere with the development of industry.

SUGGESTION FOR GREATER PATENT OFFICE

The whole subject of the validity of patents and patent rights should be dealt with by one compact organization, which could well be built around our present Patent Office. All matters dealing with the granting of patents, the status and control of patents, and the litigation relating to patents should fall within the province of this greater Patent Office.

This office could well consist of three departments: a department attending to those matters concerned with the granting of patents; a permanent patent court, before the branches of which all patent litigation should be disposed of; and a department or commission having power to establish the conditions under which monopolies resulting from the granting of patents shall be exercised.

The Patent Office should be more adequately housed than it is at the present time, and adequate provision should be made for all of its activities. The library should be made absolutely complete, and its contents should be made easily available for all of the needs of the Patent Office staff, and for such of the public as choose to make use of it. Laboratories should be provided in which the inventor should be made to demonstrate the proven workability of his invention, if it be demonstrable without large or elaborate installations. These laboratories should also be available for the demonstrations necessary in illustrating the inventions involved in patent litigation.

The patent law and practice should be so modified that every application for patent should be published, and that opportunity should be given to all who consider that they possess rights which will be abridged by the granting of this patent to set forth their rights through simple and expeditious procedure, accompanied by an absolute minimum of red tape.

As previously stated, no patent should be granted for

anything but a complete and workable invention; and no patent should be granted for improvements which must be the natural outcome of the application of reasonable engineering ability and skill to the solution of engineering problems. A patent should be made much more difficult to obtain, but much more easy to defend when once obtained.

All litigation relating to the validity of patents should be heard by special courts forming an integral part of the Patent Office. These courts should be given discretionary power as to what issues should be heard before them, and what evidence should be entertained, so that it should be impossible for patents and the patent courts to be made a means by which inventors or the public could be unnecessarily harassed.

It should be possible for anyone to institute proceedings to determine the validity of a patent, so that this matter might be determined without the necessity of first infringing the alleged rights of the patent and running the possible risk of being assessed damages for such infringement.

All litigation relating to the validity of patents should be heard before courts consisting of at least two members of the Patent Office's regular judicial staff, who, by training and experience, are particularly conversant with the branch of industry to which the patent litigation pertains, sitting with at least one other member of the regular judicial staff of the Patent Office who has had special training and experience in the patent law.

ADJUDICATION WITHOUT APPEAL

It appears to a layman that there should be no possibility of appeal from the decision of this court. The whole theory of appeal involves the assumption that it is possible, when a case has been once passed upon by a court, to find a more competent court to hear it again, and so on through the series of courts to which appeal may be taken. No court which is not competent to give a final decision upon a case should be allowed to try it at all; and when the court which is competent to give a decision in the case has once passed upon it, that case and the issues involved therein should be forever closed.

If this assumption is not well taken, and it is necessary to provide for the possibility of appeal of cases from the court of first instance, it could be provided that a court of appeal, also a regular part of the Patent Office, and constituted of experts in technical matters and patent law, should have power to order, upon proper showing of necessity for doing so, a review of questions involving the interpretation of patent law, by a court consisting of all the regular law judges of the department sitting *en banc*, from whose decision no further appeal could be taken, and which could also under conditions warranting such action, provide for the review of questions of fact before judges especially selected by it from the regular judicial staff, whose decision should be final. But special stress should be laid by the law upon the fact that great injustice is done by delay in disposing of patent litigation.

All procedure before the patent courts should be so simple that the poorest inventor could, if necessary, defend his own case unaided. When advisable, sections of the patent courts should hold their hearings in other cities than Washington, D. C.

As it is possible for the owner of a patent to place unnecessary obstacles in the way of the development of arts and industries, by withholding improved processes or apparatus from use; by making extortionate charges for the use of patented processes or apparatus, or by monopolizing improvements perfected by others, as a consequence of possessing earlier patents covering improved inventions, provision should be made for revoking patents not put to successful use within a reasonable length of time, and for determining the charges that may be made for use of patented inventions and the types of contracts under which they may be disposed of.

TAXATION OF PATENTS

Several foreign governments regularly tax patents. It is probable that public interest would be served if our Government should charge an annual license fee for every patent for each year of its life after two years from the date of issue, and forfeit all patents for which this annual fee is not promptly paid.

If it is impossible, during the first two or three years after a patent is granted, to establish its value to such an extent that the inventor can afford to pay an annual license fee or tax to keep his rights alive, the patent should be allowed to lapse and the rights of the public should be no longer abridged by it.

These annual fees would not have to be large to furnish adequate funds to support the organization herein outlined and provide ample revenue so that such salaries could be paid as to command and retain the services of the ablest type of men.

The judicial staff should be so large that all matters coming before it should be finally disposed of within six months at the most from the time actions are commenced.

Long periods of uncertainty as to the rights of the inventor and the public are so prejudicial to the development of industry that they should not be tolerated by a business-like nation. Public business should be dispatched with the promptness and thoroughness demanded in private business.

If the modifications of law and practice herein suggested should be adopted, all of the rights of the inventor and of the public could be adequately protected; invention would be stimulated, as inventors would realize that if their inventions were truly patentable, they would obtain patents therefor which could be cheaply defended; and progress in the development of the arts and industries would not be retarded through the great expense and long periods of waiting now required to determine whether or not patents which have been granted by the United States Government convey any defendable rights..

AN ENGINEER.

A Modified Iron-Carbon Diagram

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In my work with the Chinese students during the past four years a constant effort has been necessary to simplify and clarify problems, especially of a practical nature, owing to the fact that the Chinese methods of education in the past have not been given to practical lines but more to the training of the memory.

Further, when we consider the fact that the peculiarly rigid and inelastic form of the language does not allow of its being readily adapted to technical expressions or terms, and that the student has first to learn a foreign language which is fundamentally different from his own, both in methods of writing, construction and expression, it stands to reason that not only is it necessary to use the simplest expressions and clearest explanations possible, but also carefully to avoid the least possibility of confusion in the presentation of ideas or practical facts.

Among other things we have, for instance, the study of metallography in relation to the alloys, more especially that of iron-carbon, in the study of the metallurgy of iron and steel.

Of course, we all know that there are some very mate-

rial differences between authorities regarding some of the points included in the equilibrium diagram and some of them have led to rather puzzling questions from the students.

As we endeavor to make our work on iron and steel as thorough as possible it became quite necessary to take up these differences and if possible, to harmonize them so as to relieve the minds of the students of any confusion or distrust as to accuracy.

The text books used are Stoughton's "Metallurgy of Iron and Steel," and Hofman's "General Metallurgy," with references to Sauveur's "Metallography of Iron and Steel," Howe's "Iron, Steel and Other Alloys," and Tiemann's "Iron and Steel" for definitions.

A metallographic laboratory has recently been equipped with apparatus for grinding, polishing, etching and photographing as well as for recording recalescence curves for the better study of metallography in general as well as in special work.

As Sauveur is taken as a guide in the metallography, and Stoughton as a text book in the metallurgy of iron and steel, I soon came up against these disagreements of statements and it became necessary to harmonize them, as stated before, or to leave one authority discredited.

BOUNDARY BETWEEN CAST IRON AND STEEL

The first point to be considered was that of the location of the boundary line between steels and cast iron. On page 6 of Stoughton, second edition, 1911, he says,

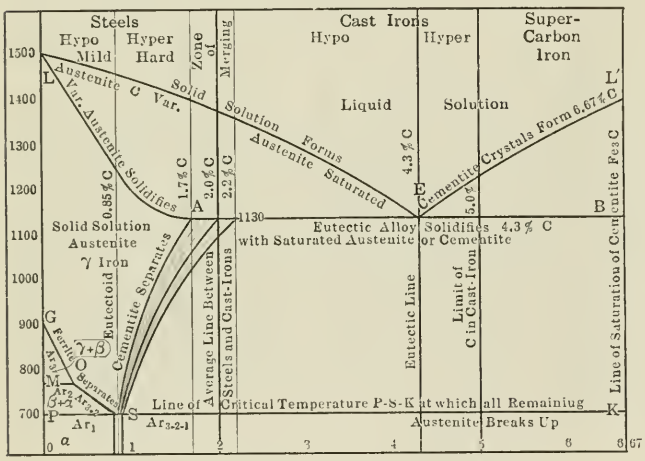


FIG. 1—MODIFIED IRON-CARBON DIAGRAM

"Cast iron generically is iron containing so much carbon or its equivalent that it is not malleable at any temperature. * * * The committee[1] recommends drawing the line between cast iron and steel at 2.20 per cent carbon for the reason that this appears from the results of Carpenter and Keeling to be the critical percentage of carbon corresponding to point *a* in the diagrams of Roberts-Austen and Roozeboom."

Again (*ibid.*), "It is because of this difference in the freezing of the alloys that the line *XY* (at 2.2 per cent) is arbitrarily considered as the dividing line between steel and cast iron."

Howe, in his "Iron, Steel and Other Alloys," second edition, 1906, page 170, says, "Fortunately there is one criterion which may be adopted for discriminating between all the various classes of steel on one hand and those of cast iron on the other, a criterion which we may apply to all future varieties of iron when we seek to decide whether they ought to be called steel or cast iron. This criterion is malleableness in at least some one range of temperature; we may adopt it because such malleableness is probably the only important specific property which all steels of to-day have and all cast irons of to-day lack, if we except the special product known as 'malleable cast iron.' * * * Cast iron, iron containing so much carbon or its equivalent as not to be malleable at any temperature, * * * the dividing line between steel and cast iron may, for the present, be put arbitrarily at 2 per cent of carbon." Again (*ibid.*) on page 195, "In this work the dividing line between cast iron and steel has been arbitrarily drawn at 2 per cent of carbon, in rough accordance with commercial usage."

Sauveur, in his "Metallography of Iron and Steel," first edition, 1912, Lesson XIX, pages 5-6-8, says, "It will be evident that, starting from carbonless iron, as the carbon increases, at first low-carbon steel is produced and then in succession medium high-carbon steel, high-carbon steel and finally white cast iron, each metal passing gradually into the next without any sharp line of demarcation between them. It is logical to base the distinction between high-carbon steel and white cast iron upon the malleability of the former and the non-malleability of the latter and this is altogether a question of carbon content. The dividing line may be drawn somewhat arbitrarily at 2 per cent carbon. *As a matter of fact steels are very seldom manufactured containing more than* 1.75 *per cent carbon while white cast iron rarely contains less than* 2.25 *per cent carbon. Between the steel series, therefore, and the white cast-iron series there is a natural gap, the existence of which generally removes any doubt as to the nature of the metal under examination.* Again if the process of manufacture be known there need be no doubt as to the classification of any highly carburized iron alloy; if made in the blast furnace from the reduction of iron ore, it is cast iron, while if it is the product of refining cast iron, * * * or of the remelting under oxidizing conditions of iron or steel scrap, with or without cast iron, * * * or of the carburizing of wrought iron, * * * or of the carburizing and melting of wrought iron, it is steel. * * *

"The portions of the diagram corresponding respectively to the steel series and to the cast-iron series have also been indicated, leaving two groups of alloys unrepresented by industrial products, namely, those containing between 1.70 per cent and 2.25 per cent carbon and those containing more than 5 per cent carbon. * * * (Footnote:) Again some unimportant products are offered for sale under the name of semisteel which may contain between 1.75 and 2.5 per cent of total carbon entirely combined, forming, therefore, a sort of connecting link between the steel and the cast-iron series. They are frequently obtained by remelting cast iron in cupola furnaces in the presence of considerable iron or steel scrap. Washed metal likewise may contain between 1.75 and 2.5 per cent of total carbon entirely combined, but this is a semi-finished product resulting from a partial refining only of cast iron."

Tiemann, in his "Iron and Steel," first edition, 1910, on page 44, under "Cast Iron," says, "It contains a considerable proportion of carbon (say 2.2 per cent) up to about 7 per cent—usually from about 2.5 to 4 per cent, and variable percentages of other substances, such as silicon, manganese, phosphorus, sulphur, etc. It is hard and brittle and cannot be rolled or forged at any temperature." And again on page 318 under "Steel," "That form of iron produced in a fluid condition and hence practically free from slag (difference from wrought iron) which contains less than about 2.2 per cent of carbon—as a rule less than 1.5 per cent (difference from cast iron)."

Now comparing the above there must be some rea-

[1]Committee on the Uniform Nomenclature of Iron and Steel of the International Association for Testing Materials.

sonable explanation for this rather broad difference and in reading the quotation from Sauveur it is very fair to assume that he has met the point especially where he says, on page 5 of Lesson XIX, "As a matter of fact steels are very seldom manufactured containing more than 1.75 per cent carbon, etc.," quoted above.

From this it can be assumed that the circumstances under which the product is made will govern the character, i.e., under some conditions it will meet the definition for steel taken from the report of March 31, 1906, of the Committee on the Uniform Nomenclature of Iron and Steel as quoted above, and under some other conditions of manufacture will meet the definition for cast iron, even though the carbon content may be the same, and that all combined.

As a result I have drawn the lines *A-S* in Fig. 1, so as to cover the zone between these two amounts and have called it "The Zone of Merging." This extends from 1.7 per cent on the one extreme to 2.2 per cent on the other, with an intermediate line at 2 per cent as an average.

LOCATION OF EUTECTOID LINE

The next point was that of the location of the eutectoid line. Stoughton, on page 292, under "Eutectoid," says, "The alloy containing 0.9 per cent carbon is known as the 'eutectoid alloy'." Again, on page 303 (*ibid.*), "The practiced eye can usually tell; but a chemical analysis readily distinguishes, since steel with less than 0.8 per cent carbon will have excess ferrite, and that with more than 0.9 per cent will have excess cementite."

Sauveur, in Lesson V, page 4, under "High-Carbon Steel," says, "Since the introduction of increasing amounts of carbon in steel results in the formation of a correspondingly increasing proportion of pearlite and a decreasing proportion of ferrite, a degree of carburization must necessarily be reached, when the whole mass will be made up of pearlite, the ferrite having finally disappeared. This critical point in the structure of steel is attained when *the metal contains somewhere between* 0.8 *and* 0.9 *per cent of carbon, exceptionally pure steel requiring the larger proportion of carbon and impure steel the smaller for the complete disappearance of ferrite.*"

Again (*ibid.*), on the same page, under "Eutectoid Steel," "Steel containing less than 0.85 per cent of carbon, *or thereabout,* and in which, therefore, some free ferrite is present, is called 'hypo-eutectoid,' while steel more highly carburized than eutectoid steel is called 'hyper-eutectoid'." Again (*ibid.*), on page 9 of the same lesson, he demonstrates the theoretical percentage of carbon in "pearlite" as being 0.834.

Tiemann, on page 185, under "Pearlite," says, "A eutectoid of cementite and crystallized iron formed by slow cooling past Ar_1. * * * It should be regarded as a variable mixture, for in structural steels containing between 0.5 and 1 per cent manganese, the carbon in pearlite varies between 0.6 and 0.9 per cent, and in some tool steels, according to the method of treatment, the pearlite accompanied by free cementite may contain 1 per cent carbon."

From these authorities we may assume that the eutectoid, depending on varying conditions, may ordinarily lie anywhere between 0.8 and 0.9 per cent carbon and have a general average of 0.85 per cent in accordance with the statement of Professor Sauveur. This I have assumed in my diagram, making the eutectoid area extend from 0.8 to 0.9 per cent, in accordance with the above.

The liquidus line from *L* to *E* has been assumed as being slightly curved, following Carpenter and Keeling's equilibrium diagram shown on page 18 of Lesson XXIII of Sauveur.

The solidus line from *L* to *A* has been made in accordance with Rosenhain, as explained on page 20 of Lesson XXIII of Sauveur.

A limiting line has been placed at 5 per cent carbon as the limit of carbon usually in commercial irons, according to Sauveur's statement from page 8 of Lesson XIX as quoted above, from the fact that these irons seldom carry more than 5 per cent carbon. Those carrying more than this amount I have designated as super-carbon irons, in order to have some distinguishing term.

EDWIN A. SPERRY.

Pei Yang University,
Tientsin, China.

The Western Metallurgical Field

Two Historical Notes on Flotation

With the rapidly increasing use of the oil-flotation process of concentration, and the consequent investigation of various processes and search of the literature on the subject, it is interesting to note some of the earlier work. It will be found true in many instances that various investigators observed certain effects that are now well known, but which may have been passed over at the time without a full realization of their value and importance.

Flotation by means of a stiff froth produced by violent agitation of an ore pulp to which oil has been added, is now one of the most common forms of the process. An interesting early reference* to the froth or foam effect is to be found in the *California Journal of Technology* for November, 1903, in an article by Messrs. W. F. Copeland, Drury Butler and James H. Wise. The authors presented some experiments on the Elmore process of oil concentration, which at that time was comparatively new. After describing their experimental work on a variety of ores, they close the article with this interesting reference:

"**Foam Effect.**—The foam effect is produced by a violent agitation, especially in acid or salt solutions. This throws the oil into a froth, which is heavily charged with air or other gases. This gas, of course, gives a greatly increased buoyant force. The oil in this condition assumes a certain load of mineral and holds it in a very stable condition. The charge does not settle and overload on standing as in the case of the lake effect. The foam effect is best adapted for light, flaky minerals, such as molybdenite."

In contrast to the stiff froth or foam formed by violent agitation, there has come into prominence more recently a process making use of a light and less coherent froth, produced by the introduction of air or gas through a porous medium; so that it enters the pulp in a finely divided condition. This effects a gaseous flotation of mineral particles. The froth thus produced breaks down more readily than some of the stiffer froths produced by violent mechanical agitation, and this feature is an advantage in many respects, particularly when the floated concentrate contains two minerals, say lead and zinc sulphides, which are to be separated on tables.

The principles of this method were described by T. J. Hoover and Minerals Separation, Ltd., when in 1910 they secured British patent No. 10,929, based on this method of flotation. But as far as known they did not secure patent in the United States. A quotation from the specification is instructive.

"According to this invention the method of introducing air or other gas into an ore pulp for the purpose of effecting flotation of certain particles consists in bringing the ore pulp into contact with a porous medium

*Compare also the report on the flotation suit in July issue, page 409.

through which air or other gas is caused to pass. Thus according to one method the pulp is introduced into a vessel having one or more porous walls through which air or other gas can be caused to pass.

"The porous media employed according to this invention may consist of plates of porous ceramic material, porous bricks, coke, or felt or other fibrous material suitably supported.

"The gas which is caused to pass through the porous medium into the ore pulp may be air or furnace gases, or it may be a gas produced chemically such as carbonic acid liberated from a carbonate or the gas may be produced electrolytically, or the gas which is passed through the porous medium may act both as selective agent and as frothing agent; a gas such as formaldehyde or carbon bisulphide vapor can be thus employed. The introduction of the gas through the porous medium may be effected either by pressure or by suction."

Metallurgy of Low-Grade and Complex Ores of Utah

In spite of the wonderful advance made in handling economically the low-grade and complex ores of Utah, as instanced by the work of the Utah Copper Company and others, a varied problem still remains to be solved. Utah's eminence as a mining State lies mainly in her large supply of low and medium-grade ores, some of which are quite complex and require careful metallurgical treatment. Fortunately the problem is being attacked in a systematic manner by a co-operative arrangement between the University of Utah and the U. S. Bureau of Mines. A preliminary report on the situation is embodied in Technical paper No. 90 of the Bureau of Mines, by Messrs. Lyon, Bradford, Arentz, Ralston and Larson. A careful survey of the mineral resources of the State has been made, resulting in a classification of the various types of ores. Some of these are being treated, but not in the most economic manner. Suggestions are made for improvements in treatment that will return a larger net profit to the owner.

Among processes having a possible application to Utah ores, the following are mentioned: For lead carbonates carrying silver; the Murex process, combining oil selection and magnetic separation; sulphidizing and flotation, converting the oxidized minerals to sulphides by hydrogen sulphide and then floating; electrostatic separation, after first coating the particles by the sulphidizing process.

For oxidized copper ores carrying gold and silver: Chloridizing and leaching; sulphidizing and flotation; leaching with ammonia-cyanide solution, according to the Mosher-Ludlow process; leaching with hypochlorous acid, according to the Slater process.

For oxidized zinc ores, occasionally carrying gold and silver: Igneous concentration, producing zinc oxide for pigment or further reduction; leaching with ammonium carbonate solution; leaching with sulphur dioxide solution, as proposed and tested at Swansea, Wales; leaching with acid solution, and electrolytic precipitation of zinc.

For oxidized zinc-lead ores, occasionally carrying gold and silver: The bisulphite process just mentioned, dissolving the zinc and smelting the lead residue; leaching with ammonium carbonate solution; sulphidizing and flotation, separating lead from zinc, the latter not being affected.

For oxidized ores of zinc and copper, carrying gold and silver: Leaching with ammonium carbonate solution and separating by electrolysis; the bisulphite process; leaching with acid solution and electrolytic precipitation; igneous concentration, recovering zinc oxide and smelting the copper residue.

Utah has an abundant supply of raw materials that can serve as reagents for carrying on many of these processes. An unlimited supply of salt is at hand, associated with mirabilite (Na_2SO_4), from which numerous reagents can be prepared. Sulphuric acid could be produced at smelting plants, and sponge iron for use as a precipitant can be prepared from many iron ores in the State. Coal and coke are readily obtained, and acid-resisting hydrocarbons for vat lining exist in large quantities. In short the State offers a wonderful field for the investigation of the problem that has been so ably presented in the preliminary report.

Workmen's Compensation Insurance in Colorado

Since the adoption of workmen's compensation insurance in Colorado at the last general election, the State industrial commission has been engaged in settling premium rates for various lines of industry. The rates that should apply to the mining and metallurgical industries have been the subject of much concern, for it was felt that such rates might easily be made oppressive, inasmuch as the mining industry cannot add the cost of such insurance to the price of metals and thus distribute the burden among consumers. Rates have now been settled, however, and the industrial commission has notified private insurance companies that it will approve the following premium rates per $100 of payroll: For underground employees in metalliferous mines, $3.75; for surface workers at mines of the same class, $2.39. Where employers supply medical and hospital service in accordance with the law, 25 per cent of the rate will be cut off. Previous to the action by the industrial commission, private companies had filed an average rate of $3.85 per $100 of payroll. The rates approved by the industrial commission will probably induce most mining companies to take their compensation insurance with the State fund. In the case of coal companies a rate of $6 per $100 of payroll has been approved. The larger coal companies may form a mutual insurance company to carry their compensation insurance.

Increased Valuation of Joplin Output

According to the Joplin *News-Herald* the value of zinc and lead ores produced and shipped from the Joplin district for the first half of 1915 is $11,303,654, as compared with $7,620,268 for the first half of 1912, which was the previous banner year. The aggregate production for 1912 was valued at $18,043,379, but this will be exceeded this year if the mean weekly valuation reaches $260,000. Of late the weekly valuation has been averaging $500,000, so that from present indications the value for 1915 will break all records. Comparative figures for the first half years 1912 and 1915 are given below:

	Shipments		Values	
	1912. Lb.	1915. Lb.	1912.	1915.
Blende	253,681,839	276,290,830	$6,203,554	$9,772,546
Calamine	16,016,160	22,470,472	241,678	479,964
Lead	51,993,604	42,753,990	1,175,036	1,101,144

Company Reports

The ninth annual report of the **Buffalo Mines, Ltd.**, Cobalt, Ontario, Canada, covers the yearly period ended April 30, 1915. The low price of silver, the high cost of supplies and the shortage of power combined to make unfavorable conditions for production and marketing during this period. The concentrating mill and cyanide plant were closed for four months, and subsequent operations were on three-fourths time, so that the report really covers little more than six months' production. The financial statement shows net income of $79,690. A dividend of $50,000 was paid. The total surplus is

$379,968. The concentrating mill treated 51,667 tons of ore averaging 19.5 oz. silver. The recovery by concentration was 72.22 per cent. The cyanide plant treated 8385 tons of slime averaging 9.86 oz. silver, recovering 82.26 per cent. The amalgamation plant and refinery treated 4925 lb. of high-grade ore, 163,865 lb. of jig concentrate, 547,010 lb. of table concentrate and 3600 lb. of metallics from the low-grade mill, and 11,967 lb. of precipitate from the cyanide mill, all containing 409,525 oz. of silver. The total recovery from the plant was 442,299 oz. silver, the excess being process silver from ores previously treated. The total production for the year was 822,791 oz. of silver. Ore reserves are estimated at 42,000 tons that will average 20 oz. per ton. The plant for cyaniding sand tailing has not been built as present conditions do not warrant the expenditure. Recovery of mercury from the amalgamation residues amounted to 41,850 lb.

The annual report of the **McKinley-Darragh-Savage Mines**, Cobalt, Ontario, Canada, for the year 1914, shows a production of 1,396,540 oz. of silver, of which 1,159,154 oz. came from the McKinley and the balance from the Savage. The total silver shipped to Jan. 1, 1915, from these mines is 14,123,525 oz. Ore reserves are estimated at 68,011 tons, containing 2,132,820 oz. of silver. A brief statement of milling operations is given below.

	Tons treated	Oz. silver per ton	Oz. silver per ton tailings	Percentage extraction
McKinley ore	45,098	24.10	3.54	85.14
Savage ore	21,656	13.37	4.85	64.13

The cost of milling McKinley ore is given as $1.442 per ton milled, and for Savage ore, $0.714.

Beaver Consolidated Mines, Ltd., experienced the same difficulties in 1914 that befell the other companies operating in the Cobalt district. The outbreak of the war caused a cessation of operations, and the mill was closed for two weeks in August. The shortage of power and the low price of silver have also had an adverse effect. The mill treated 26,724 tons of ore, recovering 415,708 oz. of silver in concentrates. Earnings amounted to $158,465. The cost of silver production was $21.54 per ounce. One dividend of $60,000 was paid.

The **Calumet & Arizona Mining Co.**, in common with other copper companies, curtailed production 50 per cent last August. The output for the year 1914 was as follows:

	Pounds copper	Ounces gold	Ounces silver
Domestic ores	49,992,909	19,745	573,606
Purchased ores	2,675,020	4,377	348,537
Totals	52,667,929	24,122	922,143

The net cost of refined copper, crediting value of precious metals, was 9.19 cents per pound. Operating cost at the smelter was reduced 35 cents per ton as compared with the cost in 1913. The blast furnaces treated 403,269 dry tons of ore and 31,299 tons of slag and by-products. The reverberatories handled 238,095 tons of charge. The roasters treated 209,138 wet tons, the average sulphur content of the ore being 27.5 per cent, and of the calcines 9 per cent. The converters produced 32,059 tons of blister copper, and treated 24,823 tons of silicious material. The New Cornelia Copper Company was acquired during the year, and a large amount of experimental work was done on a treatment process. A hydrometallurgical scheme was tested in a 1-ton plant for six months, and later in a 40-ton plant. In the 1-ton plant an extraction of 80.07 per cent was obtained. Copper was precipitated electrolytically at the rate of 0.982 lb. per kilowatt-hour. All the acid necessary was regenerated except a deficiency of 1.4 lb., 100 per cent acid per pound of copper. The report states that the process has been worked out and that future changes will be in detail only. It is understood, however, that flotation has since been adopted.

The Iron and Steel Market

Throughout the iron and steel markets there was decided improvement in July, despite the fact that usually July ushers in a "summer dullness" for the trade. In the steel trade proper the closing days of June witnessed a very material increase in the volume of shipping orders booked, due in considerable part to the fact that in certain commodities there were relatively low-priced contracts that expired June 30, and if specifications were not furnished the tonnages would be canceled. Instead of the activity decreasing in July, however, it increased. The increased demand has been well distributed. The freight car builders, who had booked large orders in May and June, totaling about 50,000 cars for the two months, began to specify freely for the steel required. The agricultural implement trade began to specify against its new manufacturing season. The automobile trade began active preparations for its new season. Export demand increased, for both war and peace materials.

Perhaps the most important influence of all, by a long range view, was the fact that in certain finished steel products the mills began to fall somewhat behind in deliveries. For many months buyers of all products had been in the habit of depending upon very prompt mill shipments, even in the case of orders calling for a wide variety of sizes and descriptions of material. In normally active times, buyers, both jobbers and manufacturing consumers, must carry stocks, for the mills make up their rolling schedules weeks in advance, making as long runs as possible on a size, and thus avoiding frequent roll changes. When orders are scarce they are naturally very accommodating. When the delivery period lengthens from two or three days, or a week, to four or six weeks, as has lately been the case with many commodities, the buyer at once begins to order more material, so as to accumulate a stock. The procedure is well known in the steel trade, and it is recognized that if at any time the mills fall somewhat behind in deliveries demand will take care of itself for quite a period. This extra demand is now being experienced.

Approximately 100 per cent of the open-hearth steel making capacity was engaged during July, and between 70 and 75 per cent of the Bessemer capacity. Open-hearth steel promptly became "scarce," open-hearth billets and sheet bars commanding a premium over Bessemer, as has always been the case in recent years in periods of activity. Steel production at the close of July was at a rate between 85 and 90 per cent of capacity, against about 70 per cent in April and not over about 35 per cent last December.

Our review a month ago noted that in striking contrast with conditions obtaining in the steel market proper the related markets in coke, scrap and pig iron were dull and relatively soft. This anomaly has now disappeared, more activity being shown in these lines, with an advancing tendency in prices. Connellsville furnace coke, which had practically gone begging at $1.75 on contracts for the second half of the year, stiffened to $1.75 for the third quarter and to $2 for the half year, while spot coke, easy in June at $1.50, advanced to about $1.70. Scrap has been more active in all markets. Just after the middle of July heavy melting steel delivered at Pittsburgh mills advanced from $11.75 to $12.75.

Pig Iron

The total pig iron turnover in July was not large, as pig iron sales go, but the volume of business on the whole was considerably larger than in June or May, all markets showing a stiffening tendency, while some ad-

vanced. A development of the month was the withdrawal of the low prices the lake front furnaces had been making in territory normally tributary to other pig iron making districts. Cleveland pig iron had been sold even in West Virginia, and there had been free offerings in Pittsburgh territory in competition with nearby and valley furnaces. The most spectacular transaction was that by which the Cleveland Furnace Company sold about 40,000 tons of basic pig iron to the Youngstown Sheet & Tube Company at not over $13, delivered, this being the first time in history that lake front pig iron was sold to the Mahoning Valley. Not so very many years ago valley pig iron was shipped to Cleveland. Conditions changed after this sale and the valley furnaces resumed sway in the territory usually regarded as their own, and their prices advanced slightly. The Republic Iron & Steel Company bought 16,000 tons of Bessemer pig iron at $14, valley furnace. We quote No. 2 foundry, delivered Philadelphia, $14.25 to $14.50; f.o.b. furnace, Buffalo, $12.50 to $13; delivered Cleveland, $13.50; f.o.b. furnace, Chicago, $13 to $13.50; f.o.b. Birmingham, $9.75 to $10; at valley furnaces, 95c. higher, delivered Pittsburgh; Bessemer, $14 to $14.25; basic, $13; No. 2 foundry, $12.75 to $13; malleable, $12.75 to $13; gray forge, $12.50 to $12.75.

Steel

Market prices on billets and sheet bars advanced sharply during July, not so much by reason of heavy demand in the market as because of heavier specifying by consumers on regular contracts, greatly reducing the tonnage the producers were able to offer in the open market. Subsidiaries of the United States Steel Corporation bought a total of nearly 150,000 tons of billets and sheet bars from mills in eastern and western Pennsylvania, Ohio, and even from one mill in Kentucky, cleaning up all the relatively cheap steel. The market scarcity is only of open-hearth, but Bessemer steel producers have not hesitated to mark up their quotations also, assuming that the market would pay within 50 cents or $1 as much for Bessemer as for open-hearth steel. The market is excited, and it is possible more would have to be paid than quotations here named: Bessemer billets, $21; Bessemer sheet bars, $21.50; open-hearth billets, $22; open-hearth sheet bars, $22.50, f.o.b. maker's mill, Youngstown. There is practically no steel offered by Pittsburgh mills, and the market, delivered Pittsburgh, is quotable $1 per ton over the Youngstown market. Rods are $26, Pittsburgh, and in poor supply.

Finished Steel

The large steel mills had been quoting 1.20c. on bars, plates and shapes for prompt shipment, and 1.25c. on third quarter contracts. At the close of June they withdrew the 1.20c. quotation, according to program, but there remained small mills ready to sell plates at 1.15c. or 1.20c., shapes and bars being fairly well established at the quotation of the large mills. About the middle of July the majority of the large mills withdrew the 1.25c. quotation, naming 1.30c. for any delivery, and this price became established, at least as to bars, while the smaller mills firmed up to 1.25c. on plates. Steel boiler tubes were advanced July 16 by one point or about $2 a ton. While the leading wire interest on June 30 reaffirmed its $1.60 price on nails, sales continued to be made at $1.55. At the same time it advanced painted and galvanized barb wire $2 a ton above the former official figure, and on account of the heavy demand for export this advance held quite well.

Current quotations are as follows for ordinary deliveries, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.31c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.25c. to 1.30c.

Shapes, 1.25c. to 1.30c.

Steel bars and bands, 1.30c., base; hoops, 1.30c., base.

Iron bars, 1.20c. to 1.25c., Pittsburgh; 1.30c., Philadelphia; 1.20c., Chicago.

Sheets, blue annealed, 10-gage, 1.35c.; black, 28-gage, 1.75c. to 1.80c.; galvanized, 28-gage, 4.50c.; painted corrugated, 28-gage, 1.90c. to 1.95c.; galvanized corrugated, 28-gage, 4.55c.

Tin plate, $3.10 to $3.20 for 100-lb. coke.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 57½ per cent off list.

Steel boiler tubes (less than carloads), 3½ to 4½-in., 72 per cent off list.

Structural rivets, 1.50c.; boiler rivets, 1.60c.

Railroad spikes, 1.40c. to 1.45c.

The Non-Ferrous Metal Market

No changes of marked importance have occurred in the non-ferrous metal market during the past month. Fluctuations in price have been small. Spelter and lead have declined from the previous high prices; tin has receded a little but copper remains firm.

Copper.—This market has been active and producers have been able to maintain their prices. Small daily fluctuations in price have not been permanent. Demand for brass making continues good, and this business is said to be larger than ever before. Electrolytic copper at New York is quoted at 19.45@19.65 cents.

Tin.—The metal has been plentiful and the price has receded slightly during the month. Buyers seem well stocked and demand has slackened. July tin at New York is quoted at about 38 cents.

Lead.—The high price of 7 cents in June was not long maintained, and the principal producer gradually reduced the price until it reached 5.75 early in July. This price has since been practically maintained, although smaller dealers have offered concessions. The metal is quoted at 5.60@5.75 cents, New York, and 5.50@5.60 cents, St. Louis.

Spelter.—The demand for this metal is stimulating construction of new reduction works and the rejuvenation of some old ones. Good business is reported both domestic and foreign. London quotations continue nominal and a wide variation still exists in domestic prices. At St. Louis the latest quotations are 19.75@21.75 cents.

Other Metals.—The market for aluminium has improved and prices have risen, the New York quotation being 32@33 cents. Antimony continues scarce with high prices, special brands being nominal. Quotations range from 37½ to 52½ cents for different grades. Quicksilver is strong with a good demand. The price for large lots is $94 per flask of 75 lb., New York, and $90@$95 in San Francisco. Smaller quantities bring up to $100 per flask.

Production of Radium by the Bureau of Mines

In a statement issued by Secretary of the Interior Franklin K. Lane in Washington on July 27, it is announced that the production of radium from Colorado carnotite ores by the Bureau of Mines, in connection with the National Radium Institute, has passed the experimental stage in its new process and is now on a successful manufacturing basis. He also declared that the statements made to Congress concerning the ability of the Bureau of Mines to produce radium at a greatly decreased cost over other processes had actually been accomplished and that the costs were even less than predicted.

"The cost of one gram of radium metal produced in the form of bromide during March, April and May of the present year was $36,050, I am informed by Dr. Charles L. Parsons, in charge of the radium investigations of the bureau. This includes the cost of ore, insurance, repairs, amortization allowance for plant and equipment, cost of Bureau of Mines co-operation, and all expenses incident to the production of high grade radium bromide. When you consider that radium has been selling for $120,000 and $160,000 a gram, you will see just what the Bureau of Mines has accomplished along these lines."

"The cost of producing radium in the small experimental plant during the first few months of the Bureau's activities was somewhat higher but not enough to seriously affect the final average.

"The public, however, should not infer that this low cost of production necessarily means an immediate drop in the selling price of radium. The National Radium Institute was fortunate in securing through the Crucible Steel Company the right to mine ten claims of carnotite ores belonging to them and this was practically the only ore available at the time. Since then new deposits have been opened but these are closely held and according to the best judgment of the experts employed by the Bureau of Mines, the Colorado and Utah fields, which are much richer in radium-bearing ores than any others known, will supply ore for a few years only at the rate of production that obtained when the European war closed down the mines. The demand for radium will also increase rapidly, for the two or three surgeons who have a sufficient amount of this element to entitle them to speak from experience are obtaining results in the cure of cancer that are increasingly encouraging as their knowledge of its application improves. A few more reports like that presented to the American Medical Association at its recent San Francisco meeting and the medical profession as a whole will be convinced of its efficacy. Under all the circumstances that have come to my knowledge it does seem to me that it behooves the Government to make some arrangement whereby these deposits, so unique in their extent and their richness, may be conserved in the truest sense for our people, by extracting the radium from the ores where it now lies useless and putting it to work for the eradication of cancer in the hospitals of the Army and Navy and the Public Health Service.

"The ten carnotite claims being operated at Long Park, Colorado, by the National Radium Institute have already produced over 796 tons of ore averaging above 2 per cent uranium oxide. The cost of ore delivered at the radium plant in Denver has averaged $81.30 per ton. This included 15 per cent royalty, salary of Bureau of Mines employees, amortization of camp and equipment and all expenses incident to the mining, transportation, grinding and sampling of the ore.

"A concentrating plant for low-grade ores has been erected at the mines and is successfully recovering material formerly wasted. Grinding and sampling machinery has been installed at Denver and a radium extraction plant erected in the same city. The radium plant has now a capacity of three tons of ore per day, having been more than doubled in size since last February. Before that time the plant had been run more or less on an experimental scale although regularly producing radium since June, 1914. To July 1, slightly over 3 grams of radium metal had been obtained in the form of radium barium sulphate containing over 1 milligram of radium to the kilogram of sulphates. The conversion of the sulphates into chlorides and the purification of the radium therefrom is easily accomplished, and with very small loss of material. Unfortunately, however, special acid-proof enamelware, obtainable only in France, has not been delivered of sufficient capacity to handle the crystalization of the full plant production, so that a little less than half the output, or to be exact, 1304 milligrams of radium element have been delivered to the two hospitals connected with the National Radium Institute. The radium remaining can be crystalized at any time from neutral solution in apparatus already installed, but the greater rapidity and efficiency of production of this very valuable material by the methods used have decided the Bureau of Mines to await the completion of apparatus now being built before pushing the chloride crystallization to full capacity.

"The average radium extraction of all ore mined by the National Radium Institute has been over 85 per cent of the amount present in the ore as determined by actual measurement. The amount present in the ore has been found in fact to be essentially the same as the theoretical amount required by the uranium-radium ratio. The extraction figures for the last five carloads of carnotite treated has shown a recovery of over 90 per cent in each case.

"A bulletin giving details of mining, concentration and methods of extraction is being prepared by the Bureau of Mines and will be issued early in the fall."

Columbia University Establishes a Separate Department of Chemical Engineering

Courses leading to the degree of Chemical Engineer have been offered in the Department of Chemistry of Columbia University for the past ten years but, in recognition of the rapidly increasing importance of those industries based upon the applications of chemistry, and the consequent demand for men specially trained in the fundamental engineering practices as applied to the problems of industrial chemistry, the trustees of Columbia University have established a separate department of chemical engineering which will be placed upon the same plane of importance in the Columbia Graduate Engineering School as mining, civil, electrical and mechanical engineering.

The demand for graduates to fill important positions in the rapidly developing industries of the United States has brought an ever-increasing number of students to study chemical engineering at Columbia, the registration in this subject having reached a total of eighty-one during the past year.

The new chemical engineering laboratories which were recently installed, where the students are taught to use engineering methods and engineering appliances in the study and development of chemical industry, will be provided with still further equipment during the coming summer. In these laboratories research may be conducted on such a scale as to establish dependable engineering data to serve as a basis for intelligent and accurate process design. They are equipped with apparatus to illustrate the fundamental operations of chemical and electrochemical processes, and the student learns by actual contact to apply the fundamental scientific principles to industrial problems. It was here that Dr. Rittman carried on, as a graduate student, his work in the direction of obtaining gasoline, benzol and toluol from residual oils.

The fields in the chemical industry which have been most seriously affected by the European war and in which, in many cases, the supply of European products has been entirely cut off, might be enumerated as follows:

Coal-tar dyes for use in the textile industry; synthetic drugs from which many of our most improved pharmaceutical products are made; synthetic tanning materials for use in tanning our high-grade leathers;

barium compounds; magnesium compounds and a large line of similar high-grade chemicals; chemical and decorated glassware; ferromanganese used extensively in the metallurgical industries; potash and air nitrate for use in fertilizers.

The sudden demand for many of these products has greatly stimulated the activity among chemical manufacturers. In many cases it is necessary first to develop the raw material supplies, as for example for the manufacture of coal-tar dyes, where we are required to obtain a large quantity of benzol, phenol, toluol, etc. The demand for these materials is being met rapidly by the installation of large plants for the recovery of these heretofore wasted products from coke oven gases. Such concerns as the United States Steel Corporation, Lackawanna Steel Company and other large coke producers both in the United States and Canada are now recovering these products. Similar activity obtains in other fields; for example, on account of large demands for explosives, the production of sulphuric and nitric acids is being enormously increased. Entirely aside from these abnormal developments, forced upon the chemical industry by the war, it should be noted that chemical processes are being established in other fields.

Co-operation in Chemical Export Trade to South America

In the Federal Trade Commission hearings, held in Boston in June, on Co-operation in Foreign Trade, some interesting remarks were made with request to the possibility of chemical export trade to South America. We quote from *National Foreign Trade* (Vol. I, No. 3):

Mr. **Henry Howard,** vice-president Merrimac Chemical Company and Chairman, Executive Committee, Manufacturing Chemists' Association, Boston, Mass., said:

"Our association is made up almost entirely of small manufacturers. When the war broke out, it seemed to our committee an especially good time to investigate the opportunities in South American trade in chemicals, as the German supply was being cut off.

"The first thing we ran up against was that, under the law, it was doubtful if we could form a combination to investigate and comprehensively push our export trade in South America. Eminent counsel advised us it was not safe to do it. Hardly more than three members of the association are large enough to send representatives to South America, and I question if any of them are large enough to send representatives to more than one or two countries. In our own case, there are only three articles we manufacture that would find a market in South America. We could not afford to send a representative because the cost would more than eat up any profit we might get, but we could join in an export association made up of other members of our association, or other manufacturers outside, and contribute toward the maintenance of an efficient staff in all the leading countries, because the expense, apportioned among forty or fifty manufacturers, would be insignificant.

"The great advantage of such an association is that we would be in a position to meet European competition, in foreign trade, where going singly we would not. European business is thoroughly organized and intelligently managed. Even if some of us went individually, we would be afraid, as soon as the war was over, that we would be killed out individually. The foreigners would think twice before starting a fight to eliminate the entire association."

Mr. **A. H. Weed,** secretary and counsel Manufacturing Chemists' Association, Boston, Mass., said:

"The association, upon request from Washington, prepared a tentative form of a bill necessary to permit the kind of co-operation contemplated. The bill is premised upon the idea that the law should give the absolute and unqualified right to American manufacturers to co-operate for export trade. The effect of such co-operation, whether it be by agreement, combination or association, is to be found primarily in the foreign markets where such agreements, combinations or associations are to be carried out. If the laws of the foreign country permit such co-operation and if our foreign competitors are all acting in combination, within these foreign markets, we should have the right to meet that competition on equal terms. In other words, our anti-trust laws should have no extra territorial effect.

"On the other hand, to prevent any abuses which might result from such co-operative movements, any retroactive effect which a combination might have to restrain trade in the United States, the bill has a provision granting power to the Federal Trade Commission, similar to the power which it now possesses, to restrain unfair methods of competition, under Sec. 5 of the existing law. The proposed bill, therefore, defines export trade on the one hand and 'trade within the United States' on the other."

Possibility of Extra Session of Congress and the Tariff

An important report is in circulation in Washington to the effect that President Wilson is likely to make an announcement shortly which will have great interest in connection with the tariff. This is taken into consideration at the National Capital under the influence of ideas that are reaching there from the business and financial centers of the country concerning what the attitude of the United States is to be after the war in Europe has ended.

Economists in Washington are now giving much attention to the steps that it will be necessary for the United States to take after the war has ended. In these the question of a protective tariff largely figures. Reports reaching Washington from all over the United States are to the effect that business men will be glad to see a readjustment of tariffs. It is especially obvious that the very large sums of money which are now being invested and about to be invested in the creation of new chemical industries (which will make the United States economically and industrially far more independent of other countries than it ever has been), will simply be wasted if these new industries are not to be protected by a suitable tariff and accessory measures.

Senators and other tariff makers now in Washington believe that the early fall would furnish a suitable opportunity to discuss these matters and plan ahead. For that reason there is apparently a growing advocacy of the plan to have Congress reassemble around Oct. 1. This idea obtains support from many Senators and Representatives who are obliged to come to Washington in September to place their children in school, as well as from those who are anxious to begin as early as possible upon the fight as to whether or not there shall be a great increase in the military preparedness of the United States, sure to come this winter.

Again, some Senators and Representatives are urging an early session of Congress because of the fact that almost all of the important questions at the coming session will furnish material upon which the 1916 political fight is to be waged and because the national political conventions meet in the summer of 1916, by which time, they hope Congress will have completed all of its labors. Thus, they advocate an early start this fall.

Cyanidation of Low-Grade Sulphide Ores in Colorado—II

BY H. C. PARMELEE

Caribou, Boulder County

In the early history of Colorado mining, Caribou was a well known camp in Boulder County, springing into prominence about 1869 and continuing active with a wonderful production of silver until 1893. In 1888 the famous Caribou mine was closed as a result of litigation, and the camp went into a decline which culminated in 1893 with the fall in the price of silver.[1] Through this combination of circumstances, but particularly on account of the slump in the silver market, Caribou suffered the fate which overcame other silver mining camps in Colorado. It was gradually deserted, the mines filled with water, fire devastated a once populous camp, and Caribou became a place of only historical interest.

The silver production credited to Boulder County, from 1869 to 1893 came mainly from the Caribou, Poorman and other mines, all located in a restricted area at Caribou. In round numbers, the annual silver output of the county began with 3500 oz. in 1869, rose to 348,000 oz. in 1879, dropped to 250,000 oz. in 1893, and finally slumped to 75,000 oz. in 1894. Aside from the known production of some unusually large nuggets of silver, the richness of the ore is attested by the early records which show profitable operation under a mining cost of $17 per ton, and transportation and treatment charges of $45, or a total of $62 per ton. Raymond[2] states that in 1869, 26 tons of Caribou ore shipped to the Hill smelter at Black Hawk had a gross assay value in silver of $3,217, and that in 1870, 425 tons shipped to the same place had a gross silver value of $73,772. For the treatment of low-grade material, say 60-oz. silver ore, which would not stand the cost of shipment, there was erected a lixiviation mill at Nederland, four miles from Caribou.

It can be readily appreciated that at the time the Caribou and Poorman mines were worked, a vast quantity of what was then low-grade ore was left unmined, used as stope filling or thrown on the dump. It will also be apparent that, due to the progress in metallurgy in 30 years, such an abandoned property might now become a source of profit if properly sampled and tested, and equipped with a suitable treatment plant. This possibility having been brought to the attention of Mr. Henry P. Lowe, he undertook first the sampling of the dumps, and later, after getting encouraging results from this work, the unwatering and sampling of the mines. The Cariman Mining & Milling Co. was organized and a modern concentrating and cyaniding mill was built.

The dumps were carefully and systematically sampled through trenches and shafts, large lots of material being crushed, automatically sampled and assayed. Later these same lots were used as the basis of concentration and cyaniding tests, so that a safe foundation was laid for any subsequent work that might be justified by the results obtained. The original tests were checked by an independent engineer who practically confirmed the first results. In many of its aspects the problem here presented recalls that which confronted the engineers for Stratton's Independence in sampling and testing that dump. The latter project was greater in magnitude and the valuable metal was gold instead of silver, but similar principles were involved, and, strangely enough, similar treatment was ultimately adopted at both mines, viz., concentration and cyanidation.

The sampling of the Caribou dumps showed an average silver content of from 7 to 8 oz. per ton. The gold value varied from 40 to 70 cents per ton. The quantity of ore in the dumps was estimated at 135,000 tons. The tests indicated a total extraction of 85 per cent, of which 35 per cent was by concentration and 50 per cent by cyanidation. Flotation was not considered as a possible means of treatment on account of the prohibitive royalty demanded. The unwatering and sampling of the mines revealed the possibility of securing a large tonnage of ore from filled stopes and low-grade

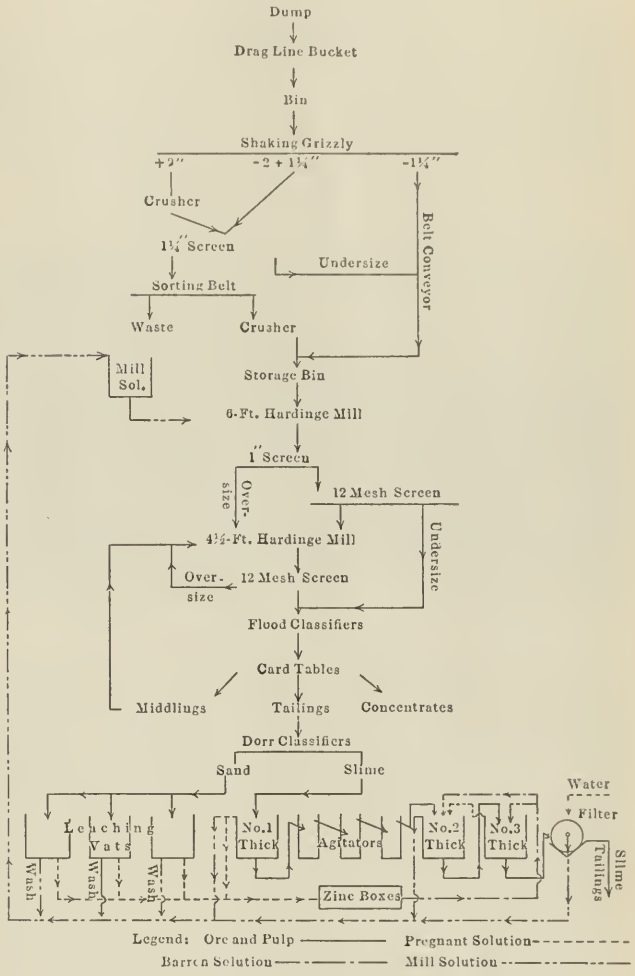


FIG. 1—FLOW SHEET CARIMAN MILL

veins that would average 15 oz. silver per ton. The final result of the sampling and testing which was carried on over a period of nearly two years, was the construction of a modern concentrating and cyaniding mill of 125 tons daily capacity, which has been in operation for over six months.

Cyanidation of Silver Ores at the Cariman Mill

The silver in Caribou ore occurs both native and as sulphide. Galena is present in small quantity, and occasionally chalcopyrite occurs. The gangue is granitic and exceedingly hard.

The ore is conveyed from the dump to bins at the coarse-crushing and sorting department by means of a drag-line bucket fitted with manganese-steel teeth. This method of reclaiming the dump has proved effective and economical, the cost averaging 4 cents per ton. From the bins the ore is fed over a shaking grizzly, with bars spaced two inches apart and below them a steel

[1]The price of an ounce of silver in 1869 was $1.32; in 1879, $1.12; 1890, $1.05; 1893, $0.78.

[2]Raymond, R. W., "Mineral Resources West of the Rocky Mountains."

plate punched with 1¼ in. round holes. The grizzly yields three products, as shown in the flow-sheet, Fig. 1. The size minus 1¼ in. is conveyed directly to the bins above the Hardinge mills. The largest size is crushed, combined with the medium size and screened through a trommel with 1¼-in. holes. The oversize from this screening operation is hand-sorted, sufficient barren granite being removed to raise the value of the mill feed from 25 per cent to 30 per cent above the gross value of the dump. Up to this point the ore is crushed dry, but beginning with the regrinding, mill solution is added. Lime also is added to the feed of the first Hardinge mill.

Hardinge conical mills have been selected for the medium and fine grinding. The first mill is 6 ft. in diameter, lined with manganese-steel ribbed plates and charged with 5-in. manganese-steel balls. The second and smaller mill is 4½ ft. in diameter, fitted with similar lining and charged with 3, 2 and 1-in balls. On account of the hardness of the ore, pebbles have not been found efficient grinders for the smaller mill.

Experience with Britannia Lining

The so-called Britannia lining, made of short pieces of rail set on end and embedded in cement, was originally furnished with one of the Hardinge mills. The lining failed after a very short run and was reset according to specifications with a strong cement mixture. After allowing ample time for the cement to set and dry the mill was again put in commission, but the lining lasted for only a few hours. The impact of the heavy balls loosened the rails and in a short time the lining was entirely broken up. Considering the time required to put this type of lining in place and allow it to set and dry, together with the very short service obtained, the experience with it was wholly unsatisfactory. Manganese-steel linings have since been used with satisfactory results.

The maximum size of feed to the first Hardinge mill is 1¼ in. The product is screened as shown in the flow-sheet, and the unground portion treated in the second mill. Twelve-mesh is the maximum size of the final product, and at this size concentration begins. There are no new features of importance in the concentrator. The pulp is hydraulically classified in Flood classifiers and distributed to Card tables. The concentrate is a finished product and is shipped to the smelter. A small amount of middling is returned to the second Hardinge mill, and the balance of the pulp, sand and slime tailing, is sent to the cyanide department.

About 35 per cent of the silver in the ore is recovered in a concentrate containing 100 oz. silver and 0.50 oz. gold per ton, with 5 per cent of lead.

Separate Treatment of Sand and Slime

The tailings from the concentrating tables flow to a duplex Dorr classifier where a separation is made between sand and slime, the dividing point being 100-mesh. The two products are about equal as to tonnage. The sand is elevated to a distributor and charged into leaching vats. Percolation begins as soon as a substantial layer of sand has formed on the filter-bottom, and continues while the vat is filling. The average rate of filling is 2.6 tons per hour, so that a 135-ton vat is under percolation for about 55 hours. During this period the solution is strengthened to 2.5 lb. KCN per ton. When the vat is full, mill solution at a strength of 1.7 lb. is turned on for about 100 hours. This is followed by a water wash for from 20 to 30 hours, according to the time available before the vat is required for a new charge. The pregnant solution obtained while filling the vat and during the wash with mill solution all flows to the clarifier and thence to precipitation. The water wash flows to the mill-solution sump. Sluicing requires from 8 to 10 hours on a 135-ton vat. An automatic sand sample is taken while the vat is filling. As the distributor revolves, the stream issuing from the longest arm passes over a slotted pipe connected with a sample box, so that with each revolution of the distributor a small quantity of the pulp is cut out.

A change made in the discharge gates on the sand vats has removed some difficulties formerly encountered. Originally the gates were of the usual type, hinged at one side and locked in place by wedges. At times the wedges would break. Again, it was necessary to have a movable launder in order to open and close the doors. The movable launder was responsible for sand spills, and at times a heavy tonnage would overflow before it was noticed. In order to obviate these troubles the doors have been tapped and threaded to receive a 6-in. plug or a 6-in. diameter pipe of suitable length to reach a permanent launder. To discharge a vat the plug is removed and replaced by the pipe which is screwed in loosely by hand. In replacing the plug it is necessary only to screw it in as tightly as may be required to avoid leakage, and if this cannot be done by hand a few turns with a wrench will suffice.

Continuous Counter-Current Decantation

The slime treatment is clearly shown in the flow-sheet. Decantation and agitation are continuous through a series of one Door thickener followed by three Dorr agitators and two Dorr thickeners. A Portland revolving filter is placed at the end of the system to recover cyanide. The overflow of No. 1 Dorr thickener is diverted either to the mill-solution sump or to the clarifier for precipitation, according to requirements. Enough of this overflow is added to the pregnant solution from the sand vats to keep the clarifying leaves submerged, and to furnish a constant supply for the zinc boxes.

The transfer of pulp from the thickeners is accomplished by means of Colorado Iron Works diaphragm pumps, which were illustrated and described in our last issue. The length of stroke of these pumps is regulated by adjusting an eccentric. At the Cariman mill the pumps are set for maximum stroke, and the quantity of pulp actually lifted is then controlled by means of an air-cock which admits air to the pump suction. No difficulty is found in thickening the slime pulp to 50 per cent moisture, and this is the standard usually maintained. Tests are made three times per shift by taking a measured quantity of slime from the discharge of the diaphragm pumps and suspending it on an ordinary spring balance with dial and indicator. A scale indicating per cent moisture, calculated from slime tables, is placed on the dial so that the moisture content is read directly.

The strength of cyanide solution is raised to 3 lb. per ton at No. 1 agitator. The agitators are run in series and the transfer of pulp is effected by gravity through adjustable transfer pipes.[3] The period of agitation is from 36 to 40 hours. On account of the sandy nature of the slime, it being ground to only minus 100-mesh, difficulty was experienced at first in keeping the transfer pipes open and pulp flowing freely. At times sand accumulated in the pipes and restricted the flow until the tanks overflowed. This has been entirely overcome by introducing compressed air through a ⅜-in. line into the transfer pipes, producing, in effect, a small air-lift. The connection between the air line and the transfer pipe is flexible so that the position of the

[3]See this journal, Jan., 1915, page 13

latter can still be adjusted as required. The quantity of air used is negligible.

The principle of impoverishing slime by decantation before filtering is now generally recognized as good practice. At the Cariman mill the function of the Portland filter is the recovery of chemicals in solution and the dewatering of the slime tailing. Dissolved silver in the slime is practically removed in the decantation process and the value of chemicals remaining in the slime pulp is greater than that of recoverable silver. A typical group of assays of filter head and tailing samples is as follows: Filter head, unwashed, 0.64 oz. silver per ton; filter head, washed, 0.34; filter tailing, unwashed, 0.42. This indicates a loss of dissolved silver of but 0.08 oz. per ton. The mechanical loss of cyanide at the filter is 0.18 lb. per ton of solution discharged in a pulp of 35 per cent moisture. Water is added as a wash in sufficient amount to balance the moisture lost in the discharged slime.

The pulp in the filter tank is kept in suspension by means of compressed air introduced from four jets spaced equidistant along the bottom edge of the tank. Once in 24 hours these jets are opened, one at a time, until all the settled slime is in suspension. The airlifts usually provided to keep the pulp in circulation have not been sufficient to prevent settlement in this particular case. They had the effect of merely pulling holes through the settled slime without disintegrating it.

The daily control of the work in the slime department requires the assay of the following pulps and solutions: Washed slime head, overflow from all thickeners, filtered solution from pulp in No. 3 agitator, washed pulp from No. 3 agitator, unwashed and washed pulp from underflow of No. 3 thickener, which constitutes the filter head; filter effluent, and unwashed filter tailing.

Precipitation and Refining

The pregnant solution from the sand vats and a varying portion of the overflow of No. 1 thickener is clarified through filter leaves under vacuum. The clarifier solution is pumped to a constant-head tank from which the zinc boxes are fed. Solution is precipitated at the rate of 1.8 tons per ton of ore. The head solution assays from 1.5 to 1.75 oz. silver per ton, and the tailing solution from 0.02 to 0.05 oz. No lead acetate is used or other special treatment given. A clean-up is made once in ten days, and a precipitate obtained assaying from 15,000 to 18,000 oz. silver and 50 oz. gold per ton.

Up to the present time no means for acid treatment have been provided, and the precipitate is given merely a light roast in a Case muffle roasting furnace. It is then fluxed and melted in a Case tilting crucible furnace. Both furnaces have gravity oil feed and air blowers, and give excellent satisfaction. A further description of the tilting furnace and burner appears elsewhere in this issue.

On account of the current high prices for chemicals, several fluxes have been tested to secure one that would prove efficient and economical. The one finally adopted contains the following materials in parts by weight: Soda, 5; borax, 3.5; silica, 1.5; manganese dioxide, 1. This has been used at the rate of 75 lb. per 100 lb. of precipitate. Manganese dioxide was selected in place of nitre, as the respective prices of the two chemicals at Denver is now about 10 cents and 20 cents per pound.

Power and Labor

Electric power is one of the modern conveniences that make possible the operation of such isolated mills as the Cariman. Situated at an altitude of over 10,000 feet and two miles from the railroad, the cost of coal delivered at the mill would be prohibitive in milling low-grade ore. Under present conditions electric power is available for all operations, and the only need for fuel is to heat the mill in winter. All motors are of ample size for the work required, as follows: Drag-line bucket, 20 hp.; belt conveyor, 5; coarse crushers, 35; Hardinge mills, 75; concentrator, 10; wet elevator, compressor and all cyanide machinery, 50.

The mill is designed to require the minimum amount of labor. All coarse crushing is done on one shift, requiring one man on reclaiming the dump and one at the crushers. In the mill there is one man per shift at the Hardinge mills, concentrator and in the cyanide department. Wages range from $3 to $4 per day.

Miscellaneous Data

The mill solution contains 1.7 lb. KCN per ton, with protective alkalinity of 2 lb. CaO. The latter may vary between 1.8 and 2.2, but outside of these limits the settlement of slime in the thickeners is seriously affected. At the sand vats the solution is strengthened to 2.5 lb. KCN, and at No. 1 agitator to 3 lb. The consumption of cyanide is 1 lb. per ton of ore, and occurs almost entirely at the agitators. The mechanical loss of cyanide in leaching is from 4 to 6 lb. per vat of 135 tons. At the filter the mechanical loss is 0.18 lb. KCN per ton of solution. The lime consumption is five lb. per ton of ore. Mine water is used throughout the mill, and solutions are kept at normal mill temperature, about 55 deg. Fahr. in winter and 65 deg. Fahr. in summer.

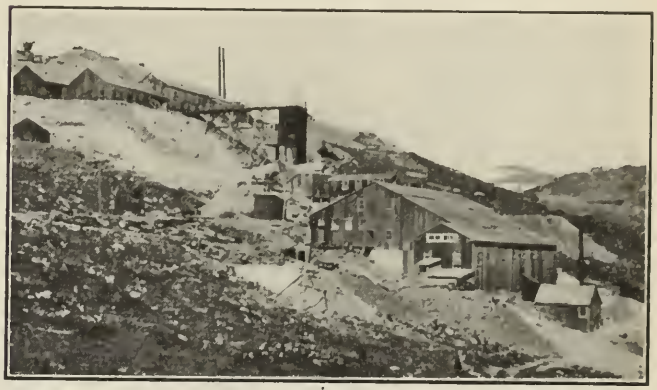


FIG. 2—CARIMAN MILL, CARIBOU, COLO.

The figures for the month of June show an average mill feed of only 4.8 oz. silver per ton. This was unusually low, due to the necessity of removing a lean part of the dump in preparation for some construction work. The concentrators recover 35 per cent. The average assay of the sand product was 2.1 oz. silver, of which 71.4 per cent was recovered. The average assay of the slime was 1.2 oz. silver, and the extraction 78.3 per cent. This amounts to a gross extraction of 85.8 per cent, or 4.12 oz. silver per ton. The total milling cost is estimated at $1.72 per ton.

The mine is now being equipped for production next winter, it being the intention to treat the dump ore only in summer. When all arrangements now planned are in working order it should be possible to maintain an average mill feed of 7 to 8-oz. ore from the dump and 15-oz. ore from the mine. The entire project affords an excellent example of revival in an old mining district, due wholly to improved methods of metallurgy and facilities for economic operation.

To Mr. Henry P. Lowe, and members of his staff, we are indebted for the data here given and for many courtesies extended in the preparation of these notes.

The Effect of High Ignition-Voltages on the Accuracy of Bomb Calorimeter Determinations

BY EDWARD J. DITTUS

In the determination of calorific values with the bomb calorimeter it is necessary to ignite the weighed portion of the substance in an atmosphere of oxygen, under pressure, by melting a small piece of iron wire (approximately 0.01 gram) with an electric current. A small calorific increment results, due to the passage of the current. It is contended that high voltages enhance this increment.

In order to determine the value of this source of error, several experiments were made with the apparatus shown in Fig. 1 and under conditions indicated.

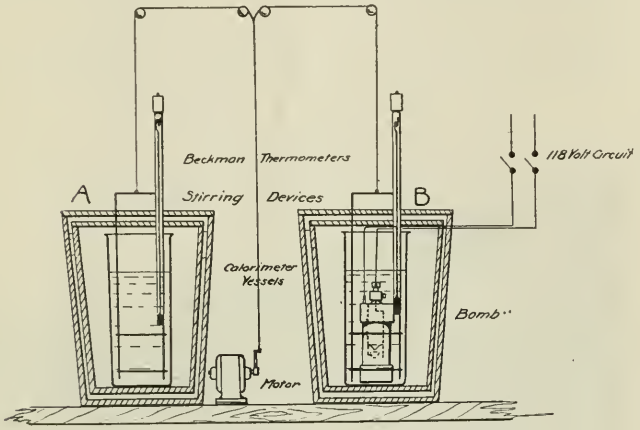


FIG. 1—APPARATUS FOR CALORIMETRY

Calorimeter A was used only as a blank to determine the variation of the temperature of the water contained, due to changes in room temperature. Calorimeter B was prepared as for a combustion, but no combustible material was introduced. No. 34 Brown & Sharpe gage iron wire was used to connect the two terminals, and the bomb contained oxygen under a pressure of 20 atmospheres. The terminals were connected to a 118-volt direct-current circuit. The two stirring devices were operated by the same motor, and the two Beckman differential thermometers were identical.

Before beginning an experiment the two thermometers were adjusted, as nearly as possible, to read the same. The difference in the reading was taken as a constant because the temperature range was in all cases very small, and the error from this source, therefore, small.

The same quantity of water (1500 grams) was used in each calorimeter, and in all experiments it was allowed to stand at least two hours in order to obtain temperature equilibrium. It was impossible to obtain the same temperature of the water in both calorimeters. Temperature readings were, therefore, made in each calorimeter until the difference was constant, and this difference assumed constant for all subsequent readings.

In making an experiment, a temperature reading was taken on each calorimeter, and immediately thereafter the 118-volt circuit was momentarily closed. Temperature readings were then taken at fifteen to thirty second intervals for ten minutes.

Three experiments were thus made and the data recorded as shown in tabular and graphic form. In the tables, the column "Corrected Bomb Temperature" was computed by adding to the "Bomb Temperature" the sum of the difference in the initial readings of the two differential thermometers and the constant difference in the temperature of the water in the two calorimeters.

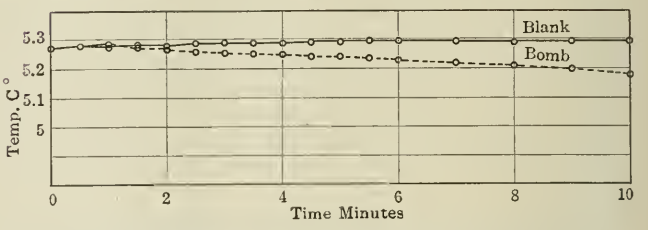
EXPERIMENT I

Weight of water in each calorimeter ..... 1500 g.

Initial difference in temperature of water	0.865° C.
Initial difference of Beckman thermometers	0.765° C.
Total difference	1.630° C.

READINGS

Time, Seconds	Temperature Blank	Temperature Bomb	Corrected Bomb Temperature
0	5.270	3.640	5.270
30	5.280	3.650	5.280
60	5.280	3.655	5.285
90	5.280	3.645	5.275
120	5.280	3.645	5.275
150	5.290	3.630	5.260
180	5.290	3.625	5.255
210	5.290	3.620	5.250
240	5.290	3.620	5.250
270	5.295	3.610	5.240
300	5.295	3.610	5.240
360	5.295	3.590	5.220
420	5.295	3.580	5.210
580	5.295	3.565	5.195
640	5.295	3.550	5.180
710	5.295	3.530	5.160



EXPERIMENT 1 WITH BOMB CALORIMETER

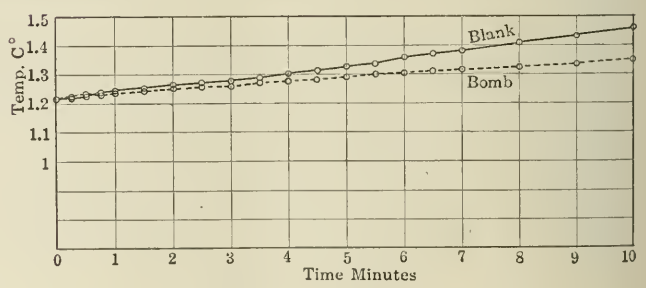
EXPERIMENT II

Weight of water in each calorimeter ..... 1500 g.

Initial difference in temperature of water	0.320° C.
Initial difference of Beckman thermometers	0.135° C.
Total difference	0.455° C.

READINGS

Time, Seconds	Temperature Blank	Temperature Bomb	Corrected Bomb Temperature
0	1.215	0.760	1.215
15	1.220	0.770	1.225
30	1.230	0.780	1.235
45	1.240	0.780	1.235
60	1.215	0.790	1.245
90	1.250	0.790	1.245
120	1.260	0.795	1.250
150	1.270	0.800	1.255
180	1.280	0.810	1.265
210	1.290	0.815	1.270
240	1.300	0.825	1.280
270	1.315	0.830	1.285
300	1.325	0.835	1.290
330	1.335	0.840	1.295
360	1.350	0.850	1.305
390	1.360	0.860	1.315
420	1.370	0.860	1.315
450	1.380	0.870	1.325
510	1.410	0.880	1.335
570	1.430	0.895	1.350
630	1.455	0.910	1.365



EXPERIMENT 2 WITH BOMB CALORIMETER

Summarizing the data obtained in the three experiments I, II, and III, we get the results given in table IV.

EXPERIMENT III

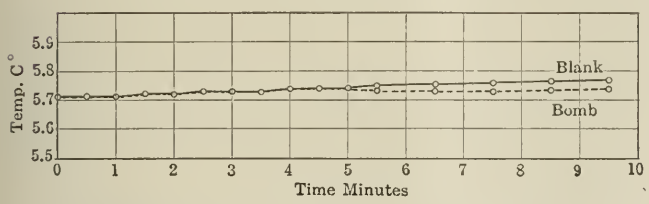
Weight of water in each calorimeter ..... 1500 g.

Initial difference in temperature of water ..... 4.020° C.
Initial difference of Beckman thermometers ..... 0.150° C.

Total difference ..... 4.170° C.

READINGS

Time, Seconds	Temperature Blank	Temperature Bomb	Corrected Bomb Temperature
0	5.710	1.540	5.710
30	5.710	1.540	5.710
60	5.710	1.540	5.710
90	5.720	1.550	5.720
120	5.720	1.550	5.720
150	5.730	1.560	5.730
180	5.730	1.560	5.730
210	5.730	1.560	5.730
240	5.730	1.560	5.730
270	5.740	1.570	5.740
300	5.740	1.570	5.740
330	5.740	1.570	5.740
360	5.750	1.580	5.750
420	5.755	1.585	5.755
480	5.760	1.590	5.760
540	5.765	1.595	5.765



EXPERIMENT 3 WITH BOMB CALORIMETER

TABLE IV

No. of Experiment	Difference in Temperature, Blank and Bomb	Resultant Error in Gram-Calories Using 1500g. Water and 0.5g. Coal	Percentage of Error on 1g. Coal on Assumed Basis of 7000 Gram-Calories
1	0.005	7.500	0.25
2	0.005	7.500	0.25
3	0.000	0.000	0 00
Average....	.....	.....	0.166

The above data lead to the conclusion that unless great accuracy is required the ignition voltage is not an important consideration. That is, in the determination of the calorific value of coal, oil, etc., an error of 0.2 per cent is permissible, and the ignition voltage need not be seriously regarded.

Metallurgical Laboratory,
Colorado School of Mines.

The new benzol plant of the Inland Steel Co. at Indiana Harbor is now practically completed. A similar plant is being installed by the U. S. Steel Corporation at the Gary works.

Silica-Graphite Paint.—A practice that is fast gaining adoption in progressive power plants is the use of paint for the inner surface of steam boiler drums. The paint is said to afford protection against pitting. Silica-graphite paint is used for this purpose and for a number of years the manufacturers of this paint have coated the steam drums of five B. & W. boilers developing 1800 hp. and as a result the drums are in almost perfect condition. Another instance, in a plant equipped with B. & W. boilers developing 8400 hp., the interiors of the drums were scalded, painted both above and below the water line and allowed 48 hours to dry thoroughly. This treatment was repeated every ten months, and not only did it stop pitting but where it had previously taken six men seven days to clean the drums of one boiler, two men now clean them in a day. This latter experience is quoted from a letter of the Chief Engineer of the New York Life Insurance Company, in the April issue of *Graphite*.

The Potash Situation

BY SAMUEL H. DOLBEAR

The pressing necessity of a source of potassium salts independent of the control of the German Kali Works has never been so apparent as now. The absolute embargo placed upon the export of potash in all forms by the German government has created a most serious situation for the potash consumer. Arbitrary treatment of American buyers by the German syndicate in the past has, it is true, created some little feeling, but heretofore the question has been largely that of price, while now the consumer finds himself unable to secure any part of his wants at any figure.

At least one source of potash in commercial quantities is now known to exist in the United States, at Searles Lake, San Bernardino County, California, and it is possible that the intensive search which has been conducted by the United States Geological Survey, the Bureau of Soils, and by private individuals may result in making known other deposits.

Proverbially, large bodies move slowly. The Searles Lake enterprise easily qualifies in such a class, and while the engineers and officials of this project are working intelligently and with as much speed as will secure ultimate results, no immediate production of potash in large quantities is expected. The problem of transportation has been solved by the construction of a branch railroad from Searles, on the Southern Pacific Railroad, to the new town of Trona, on the northwestern edge of Searles Lake. This work was done by the Trona Railway, a corporation financed by the American Trona Company, which is the operating concern. The California Trona Company continues as the owner of the property, which originally comprised about 250 placer locations of 160 acres each—a total area of approximately 40,000 acres.

The serious problem at Searles Lake is essentially a chemical one, involving the separation of potassium chloride from a solution containing also sodium carbonate, sodium chloride, sodium sulphate, sodium borate and other saline substances. The process worked out by John W. Hornsey, and for which an experimental unit designed to produce 5 tons of potash per day was built, has been abandoned as not practical. A new process has been developed by a New York engineer, which it is believed will successfully make this separation, but details of this new process have not been made public.

There is still some litigation with regard to the title to the company's claims. The California Trona Company filed application for patents on certain of its claims, and the granting of the patents has been protested by Victor Barndt. The reasons for the protest are unusual, being based on the following grounds: (1) Attempt to establish a monopoly; (2) failure of locators to make discovery; (3) that the locations were not made in good faith. The first claim hardly seems to deserve serious consideration for the reason that the presence of potash was not known to the locators when the claims were filed. Anent failure to make discovery, that is, of course, a matter to be determined by evidence. The third basis quickly resolves itself into the question of "What is 'good faith'?" The question in this case is really that of determining what is a sufficiently valuable consideration to constitute a valid transfer of title.

Aside from the work at Searles Lake, efforts have been directed along three other lines in the United States with a view toward securing a potash production: (1) From "vinasse" or refuse from a distillery in California; (2) from California kelp, and (3) from siliceous rocks in which potash occurs in an insoluble state.

During the past year the Pacific Chemical Company

commenced the construction of a plant at Agnew, Cal., on a site adjoining the distillery of the Western Grain & Sugar Products Company, and plans to use the refuse "vinasse" of the latter concern. No production has yet been made.

At Point Loma, San Diego County, Cal., the Kelp Products Company has built an experimental plant to extract potash from kelp. The plant is also designed to dry the kelp commercially for use as fertilizer. The kelp is harvested with a mower device which extends 6 ft. below the surface of the water. After being mowed the plants are carried by a conveyor into a barge. When loaded this is towed ashore to the company's wharf, on which has been placed a chopper. By means of a conveyor the plants are delivered from the barge into the chopper. From the chopper discharge the material is carried on another conveyor to a rotary tubular calciner in which a sufficient heat is maintained to thoroughly dry the chopped kelp. The dried product is then ground and sacked for shipment. According to the officials of the company, the dried product contains 15 per cent K_2O, 2 per cent N, and ½ per cent P_2O_5.

When it is desired to extract the soluble potash content from the kelp a different course is pursued. Under the patent which the company holds, a deglutinizing agent is fed into the chopper while the plants are chopped very fine. The juices are then pressed from the kelp and the residual pulp dried. The juices are then artificially evaporated and the salts allowed to crystallize.

A careful study of the chemistry of these kelps has been made under the direction of the College of Agriculture of the University of California. This institution has recently published a bulletin compiled by John S. Burd, entitled "The Economic Value of Pacific Coast Kelps."

The possibility of recovering potash from feldspar and feldspathic rocks has been very fully discussed by Messrs. Allerton S. Cushman and George W. Coggeshall in METALLURGICAL & CHEMICAL ENGINEERING in the issues of November, 1912, and February, 1915.

THE EUROPEAN SITUATION

Importations of potash into the United States were disturbed immediately upon the declaration of war in Europe, and months before Germany had established the absolute embargo, there existed what then seemed a critical shortage in supply. The extent of the interruption may be appreciated when it is known that in the fiscal year ending June 30, 1914, there was imported into the United States 1,066,929 tons of potash salts for fertilizers. Importations for the six months July 1, 1914, to Dec. 31, 1914, amounted to only 182,192 tons, as against 567,595 tons for the same period in 1913, thus leaving a shortage on Jan. 1, 1915, of 384,403 tons.

The turnover of the German Kali Syndicate in 1914 amounted to approximately 156,000,000 marks ($37,128,000), a decrease compared to 1913, when the amount was 192,000,000 marks ($45,696,000). In view of the rapid increase in production just prior to the war, it seems probable that had war not been declared the turnover for 1914 would have been about 210,000,000 marks ($49,980,000).

While authentic data regarding the present operations of the German Kali Works is not available, it is known that about one-half of its employees have gone to the front as soldiers. It is interesting to note that these men are being paid their usual wages while engaged in military duty.

There are two points of particular interest in the European potash situation at this time: the case of Alsace, and the prospect of securing a supply in Spain. In Alsace, so far as is now known, the deposits underlie an area of nearly 7 sq. miles. They range in thickness from 6 to 30 ft., and contain an estimated tonnage of 1,472,058,000 tons of potash salts. It is reported that explorations carried on in Baden, across the Rhine from the Alsatian mines, indicate the probable extension of the deposits into that section also. The future possession of Alsace is possibly now in doubt, and should the administration of that country pass out of German hands, potash from its mines might compete with the German product.

The presence of potash in the Provinces of Barcelona and Lerida in Spain has been known for several years, but only during the past year or two has general interest centered here as a possible competitor to the Strassfurth deposits. This possibility seems to have been appreciated by the German interests and much of the new fields had been taken up by them prior to the outbreak of war last year. Anticipating that German control might simply result in the complete shutting down of the mines, the Spanish government have prepared laws which require the constant operation of the deposits by those holding mining privileges. While investigations made so far seem to indicate that only enough potash may be found here to supply the demand in the Spanish markets alone, such investigations are far from complete, and sentiment in Spain does not seem to respond to the doctrine of conserving these resources for local use exclusively.

Aside from those concessions which have passed into the hands of German principals, others have been secured by French capital. All of the lands so far taken up are in a limited region along the Cardona River near the towns of Suria and Cardona. The claims do not go beyond Solsona on the north, and Tarrega, Servera and Manresa on the south. The Geological Survey of Spain is now conducting a careful investigation of this area, and while this research is being made all free lands have been reserved from entry. Under the new law, the government itself may undertake the exploitation of all minerals which can be utilized in the manufacture of fertilizers.

The American Consul General at Barcelona has reported that under the most favorable circumstances no production of potash could be made before the latter part of 1915, and that the development of these fields has been seriously affected by the present war.

OTHER FOREIGN SOURCES OF POTASH

The niter deposits of India, Chili and Africa furnish some potash salts, although the amounts produced are relatively small. About 10,000 tons is annually exported from India, while the Chilian production is about 20,000 tons. In Scotland, Norway and Japan small amounts of potash and iodine are extracted from kelp, and in Russia a small amount of potassium carbonate is made from the ashes of sunflower stalks. In Canada, potash is leached from wood ashes in the big lumber mills.

The development of a potash industry in Utah seems assured in the near future. The Mineral Products Co. has contracted for the construction of a tramway near Marysvale, Utah, for the purpose of transporting alunite to a treatment plant which is to be erected.

Ferromanganese Made at Niagara Falls.—The firm of E. J. Lavino & Company, Phila., Pa., has started the manufacture of 80 per cent ferromanganese at Niagara Falls, N. Y., and it is our understanding that they have made arrangements to supply the American trade with their future requirements. Since the war started, the supply of ferromanganese from Europe has been a source of worriment to the steel industry.

Possible Applications of Oxygen in Metallurgy

Oxygen Blast for the Iron Blast Furnace

Before the Mining and Metallurgical Society of America, Mr. **J. E. Johnson, Jr.**, discussed recently in an interesting manner some possible applications of cheap oxygen, especially in the metallurgy of iron (*Bulletin*, Vol. VIII, No. 2). In view of the fact that oxygen at lower and lower cost has become a commercial commodity in recent years, and that developments tending to reduce the cost of oxygen still further appear to be close to realization in the near future, Mr. Johnson's remarks are particularly timely and suggestive.

"One of the developments of the past five years has attracted less attention than it deserves, because its first steps were obscured by charlatanery and chicanery. I refer to the progress of separating air into its component oxygen and nitrogen on an industrial scale by distillation from liquid air, a process which is in actual operation at Niagara Falls, separating many thousand cubic feet of air per hour.

"Those who remember the ridiculous claims made for liquid air some sixteen years ago, and their subsequent utter collapse, are inclined to deny the commercial possibility of that operation, on theoretical grounds, but this is not correct. The theoretical power, figured on the basis outlined by Ostwald, the great apostle of physical chemistry, amounts to only 1 hp. per 6 cu. ft. of oxygen produced per minute. A modern 500-ton blast furnace needs 45,000 cu. ft. of air or 9000 cu. ft. of oxygen per minute, which would require, on the theoretical basis, 1500 hp. for its production, as against the 2500 hp. now necessary to blow the furnace.

"The best performance of any actual air separating operation to-day requires about seven times the theoretical amount of power, so we are still far from being able to replace existing methods on the power basis. Processes are under development, however, which promise to reduce this power requirement by one-half or two-thirds; in other words, we hope to produce oxygen at any efficiency of 50 per cent, based on theoretical power, and there is no fundamental reason why we should not do so. Even this, you will say, is no improvement over present conditions, and on the power basis alone that would be true. But this question cannot be decided on the power basis alone for two reasons: First, the heat consumption of the blast under present blast-furnace conditions is not limited to power alone. Second, the result in the furnace itself must be considered.

"In regard to the first point, it must be remembered that the blast must not only be compressed but it must be heated, and this operation requires about four times the heat required to supply power for compression; then there is the heating equipment which costs as much as the power plant, all of which would be saved by the use of oxygen. This brings us to the second point, the effect of oxygen in the furnace itself.

"In the furore which arose over the dry blast just ten years ago you may remember that a new theory of the blast furnace was brought out, which supplements the old theory in precisely the same way that the second law of thermodynamics supplements the first, and, curiously enough, is expressed by identically the same mathematical formula. This new theory rests on the fact that quantity of heat alone is not sufficient; the temperature at which it can be applied is just as important.

"We know as a matter of practical observation that a furnace will not operate properly unless the slag be raised to or above its free-running temperature, therefore that some of the heat required for the process must be supplied at or above that temperature. Since, under given conditions, the quantity of this heat bears a definite ratio to the total quantity, the first, which I call for convenience the 'hearth heat,' is just as important as the second. As a matter of fact, whichever quantity first falls below the requirements sets a limit to economy whether the other be present to excess or not, and in 95 per cent of the cases it is the quantity of hearth heat obtainable per pound of fuel which limits fuel economy.

"If we know the critical temperature it is easy to calculate this latter quantity for any given condition. I recently had occasion to calculate it for dry blast at 1000 deg. Fahr., and for a mixture of equal weights of oxygen and nitrogen (at atmospheric pressure) for different critical temperatures. The results are shown in Fig. 1. The critical temperature in ordinary coke practice is well established as about 2750 deg. Fahr., and you will see that at this temperature the hearth heat, with ordinary hot blast, is about 1600 B.t.u. per pound of coke, while with 50 per cent oxygen it is 2400 B.t.u., so that with 50 per cent oxygen blast an ore which now requires 2100 lb. of coke would require only

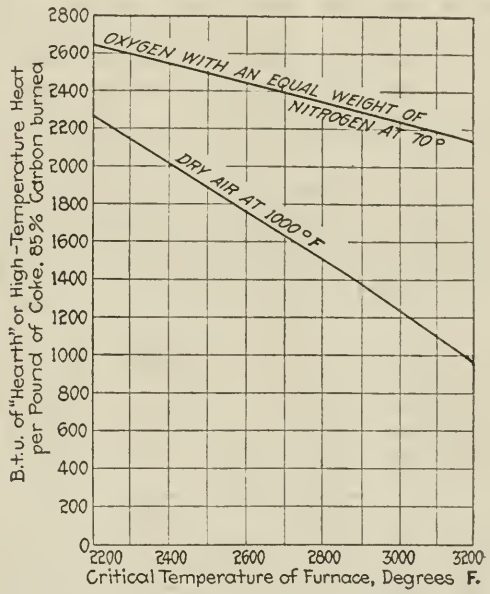


FIG. 1—DIAGRAM SHOWING HEARTH HEAT PER POUND OF COKE

Counting 85 per cent fixed C burnt in hearth, at different critical temperatures with blast of dry air at 1000 deg. Fahr., and with blast containing equal weights of oxygen and nitrogen.

1400 lb. While this is not the whole story, a very careful analysis, based on experimental data, indicates this result as entirely possible.

"This has an important effect on the consumption of power, for obviously it will require only 67 per cent as much oxygen to burn 1400 lb. of coke as it does to burn 2100 lb., and we therefore reduce our power consumption by 33 per cent to burn the same quantity of coke in each case.

"This is not all. The above computation assumed a blast containing 50 per cent oxygen, which may be obtained by mixing pure oxygen, on which our power calculations are based, with 1½ times its volume of air, which costs nothing; this reduces the pure oxygen which must be furnished to about 73 per cent. The product of these two percentages, 67 and 73, is about 49 per cent, and it thus looks as though power consumption by this suggested process might actually be less than at present, to say nothing of the saving of gas for heating the stoves. It becomes then a question merely whether the saving of 1000 lb. of fuel would pay fixed charges on the new investment; this is obviously a question of locality rather than of possibility for the present.

"There are, however, several other sides to the subject. One is the increasing leanness of the ores available; this may perhaps be best illustrated by the fact that when my father was called on to make an examination of the Chaplin mine in 1891 he found them throwing 56 per cent ore over the dump as rock. The effect of increasing the leanness on fuel consumption has already been felt, and is destined to be felt much more distinctly in the future. Ore of 52 per cent Fe produces about ½ ton of slag per ton of iron. Ore of 38 per cent Fe and 38 per cent silica produces 2.25 tons of slag, an increase of 1.75 tons, which at 0.4 ton coke per ton of slag produced means an increase of 0.7 ton in coke. In the same manner an ore with 25 per cent Fe, 48 per cent SiO_2, and 15 per cent Al_2O_3 would produce 5 tons slag per ton iron, which, at 0.4 ton of coke per ton of slag, would require 2 tons coke for slag alone, or nearly 3 tons in all.

"This would require 4.2 tons of coal per ton of iron, since to make 1 ton of coke takes 1.4 tons of coal, and the value of the by-products does not more than pay for coking.

"Moreover, we now use a large tonnage of ferromanganese and a considerable tonnage of ferrosilicon, which can be made only up to 15 per cent Si in the blast furnace; anything above this must be made in the electric furnace. In the case of ferromanganese, a heavy loss of manganese occurs because the bottom of the furnace is too cold and the top too hot. With both ferromanganese and ferrosilicon the consumption of coke is twice as much as with pig iron, though the heat requirements are but little greater. This is because the critical temperature at which the operation must be conducted is much higher. We can easily see by the chart that the critical temperature must be about 3300 deg. Fahr. to require this amount of coke, and that the available heat per pound of coke at this temperature, and with 50 per cent oxygen, is 2100 B.t.u., as against 800 B.t.u. with ordinary hot blast. In this case we may be sure that we could reduce the coke consumption to one-half with oxygen blast, and by reducing the volume and increasing the temperature of the slag we would cut down the slag loss of manganese; furthermore, the quick drop in temperature of the gases, due to their small volume, would prevent the volatilization of much of the manganese, which in present practice is being lost in that way.

"The critical temperature now attainable limits the production of ferrosilicon to those ferrosilicon brands containing 15 per cent or less Si, but a brief inspection of the chart will show that this will not be true when we use 50 per cent oxygen, and I confidently expect that we shall be able to make 50 per cent ferrosilicon in this way

"You may question the possibility of withstanding the high temperature produced by the combustion of incandescent carbon in oxygen, thinking that this will be a serious objection to the proposed process; no difficulty is to be anticipated on that score because we have no reason to expect any higher temperature with oxygen blast than we attain to-day. It must be remembered that the temperature of any combustion is determined by the total quantity of heat developed divided by the thermal capacity of the substances present. Theoretical combustion temperatures of the present blast furnace run up to 3500 deg. Fahr., but it is doubtful whether actual temperatures often exceed 2800 deg. or 2900 deg., because we charge the furnace with sufficient 'burden' to hold the temperature down to this point. With an oxygen blast, we should simply dampen the combustion with enough more burden to keep the temperature practically where it is now.

Other Applications

"The nitrogen discarded from the blast would be an asset of great value. Existing air distillation plants are run for the production of nitrogen for cyanamide, but the manufacture of ammonia by direct synthesis of hydrogen and nitrogen, without excessive power consumption, is an established fact; methods have also been developed for the production of hydrogen, both by partial liquefaction of water-gas or coke-oven gas, and by treatment of water-gas with lime. If this process be perfected we can obviously make about a pound of ammonia for every pound of iron, and at comparatively small expense. This would alter the fertilizer situation decidedly for the better.

"Many other dreams will be realized when we obtain really cheap oxygen. One of these is to obtain rich producer gas, containing a high percentage of the heating value of the coal, so that transmission of power and heat by gas generated at the coal mine will be not only feasible but profitable in many instances. To obtain water-gas by present methods, we must waste a large part of the heat value while 'blowing up' the producer, but having pure oxygen we could use a large quantity of steam with it continuously, thus producing a gas consisting wholly of hydrogen or hydrocarbons, and carbon monoxide, which would probably have a heat value of at least 500 B.t.u. per cubic foot and would afford a very high temperature of combustion because entirely free from nitrogen. By mixing a limited percentage of oxygen with city gas in the mains, its lighting power, applied to mantles, is enormously increased and it is not explosive.

"These are the phases of the subject with which I am most familiar. There are many others of almost equal importance, intimately connected with metallurgy and chemistry. Those who wish to be leaders in their particular branch of the profession would do well to ask themselves the question: 'What will probable developments in the production of cheap oxygen do for my field of chemistry or metallurgy?'"

Blue Vitriol.—Since June 1, 1915, the sale of copper sulphate, manufactured by the Nichols Copper Company, is handled exclusively by the General Chemical Co.

A preliminary report on the dye-stuff situation in the United States has been issued as Senate Document No. 952, Sixty-third Congress, and can be obtained free on application to the Senate Document Room, Washington, D. C.

Coal-tar products and the possibility of increasing their manufacture in the United States are considered in *Technical Paper* 89 recently issued by the Bureau of Mines, Washington. The paper contains also a chapter on coal-tar products used in explosives.

The production of chromium in the United States has increased since the war cut off European supplies. California is the chief source of chromium in this country. The production in 1913 was 255 long tons, and in 1914, 591 long tons. The gain in quantity was 131 per cent and in value 205 per cent.

The first ferromanganese furnace of the Noble Electric Steel Company at Heroult, Cal., was put in operation on June 3 and is reported to have produced a satisfactory cast of ferromanganese of 80 per cent grade, according to the British standard. This furnace has a capacity of 10 tons a day. Suitable ore, it is claimed, is supplied to the plant from mines in Mendocino County. The project is in the control of Mr. H. H. Noble, formerly president of the Northern California Power Company.

Vacuum Pans

Classifications, Principles, Tests

The paper by Prof. E. W. Kerr, assisted by J. F. Gunther and W. A. Rolston, on Performance Tests of Sugar-House Heating and Evaporating Apparatus, which forms Bulletin 149* of the Agricultural Experiment Station of the Louisiana State University and A. M. College, Baton Rouge, La., contains an interesting account of extensive vacuum-pan tests, made in large-scale sugar-house operation. A suggestive classification of vacuum pans is first given, with an explanation of the principles involved.

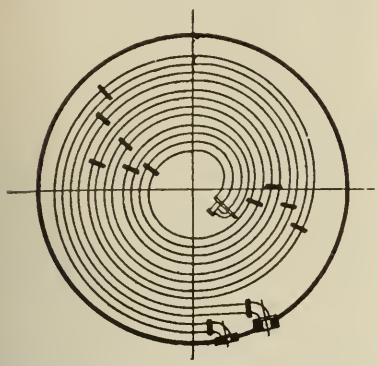


FIG. 1—COIL VACUUM PAN, DOUBLE COILS.

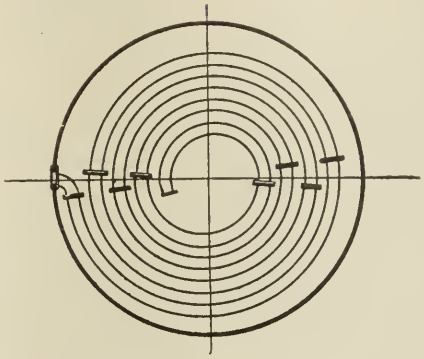


FIG. 2—COIL VACUUM PAN, SINGLE COIL

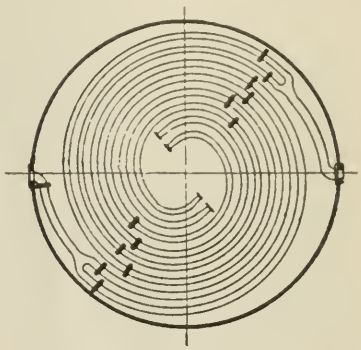


FIG. 3—COIL VACUUM PAN, QUADRUPLE COILS

Classification

There are two general types of vacuum pans (Figs. 1 to 9)—namely, calandria and coil pans. A calandria vacuum pan in the simplest form is practically of the same construction as a standard vertical-tube evaporator, except that the tubes are somewhat shorter and larger in diameter. There are several different arrangements of coil pans, a typical arrangement being shown in Fig. 4. Coil pans of this type may have single, double, triple or quadruple coils, as shown in Figs. 1 to 4 inclusive. Fig. 5 shows what may be called a manifold coil pan, there being an interior manifold for each set of coils, the steam entering the coils through the manifold and the condensation leaving from it. Fig. 6 shows another type which may be called the double manifold coil pan, steam entering the coils through one interior manifold and the condensation leaving them through another manifold.

Fig. 7 illustrates a plain calandria pan with two steam coils below the calandria. It will be noted that there is a central downtake as in standard evaporators, also a number of smaller downtakes nearer the circumference. Fig. 8 shows a calandria pan differing from the plain calandria pan shown in Fig. 7, mainly in the fact that the tube sheets are inclined. Fig. 9 illustrates another pan similar to that of Fig. 8 except that the tubes as well as the tube sheets are inclined. There are various other arrangements of calandria pans though those il-

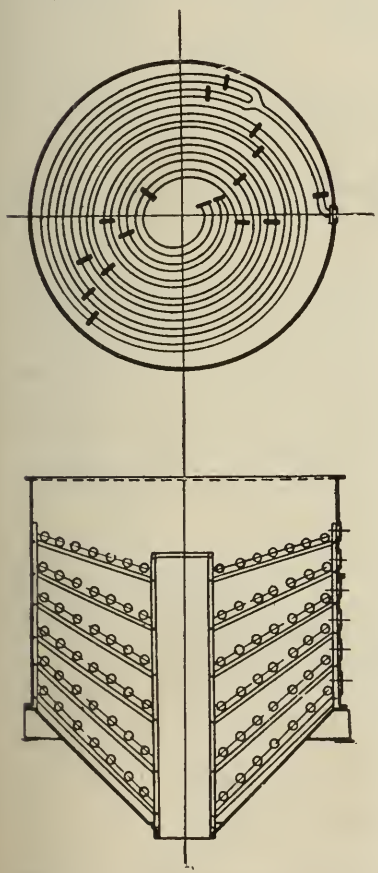


FIG. 4—COIL PAN, DOUBLE COILS

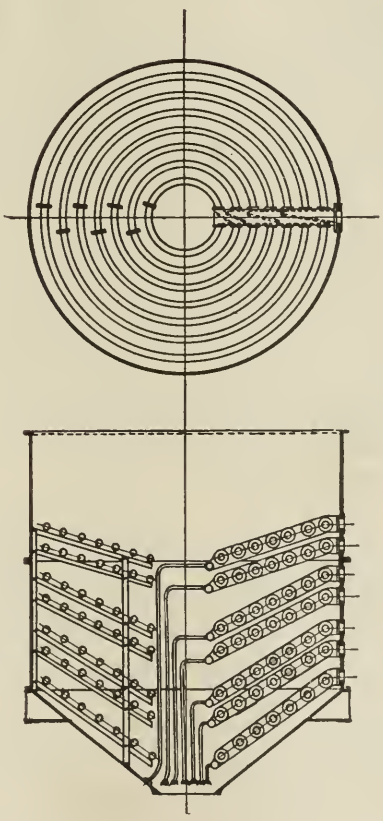


FIG. 5—MANIFOLD COIL PAN

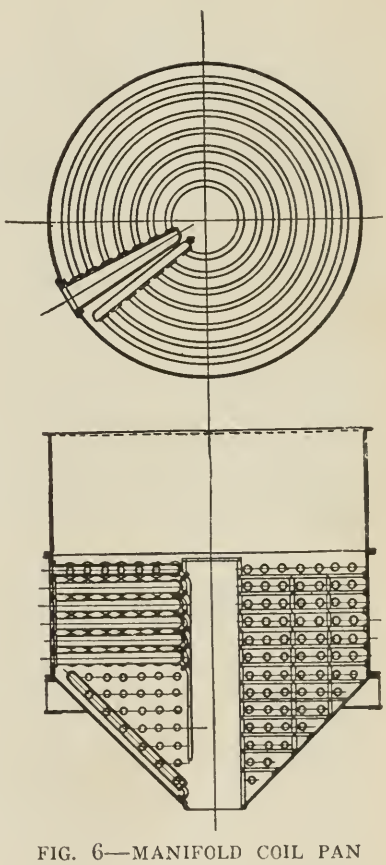


FIG. 6—MANIFOLD COIL PAN

*An abstract of the contents of this Bulletin is given in the Synopsis in this issue.

lustrated will serve to indicate the general principles involved in their design.

The factors which affect heat transmission and capacity in vacuum pans are in a general way similar to those in multiple evaporators. However, due to the difference in the arrangement and construction of the heating element, the methods necessary for meeting the requirements differ somewhat.

Principles Involved

TEMPERATURE FALL

In vacuum pans the temperature fall is generally much greater than in evaporators for the reason that the temperature difference between steam and liquid is not subdivided as in evaporators. In pans where live steam is used the pressure is usually 25 to 100 lb. gage, the average being in the neighborhood of 60 lb. gage, with a vacuum of 26 in. mercury. This would give an apparent temperature fall of 182 deg. This naturally results in a greater transmission of heat per unit of time and area than in evaporators. This applies especially to coil pans. In the case of calandria pans,

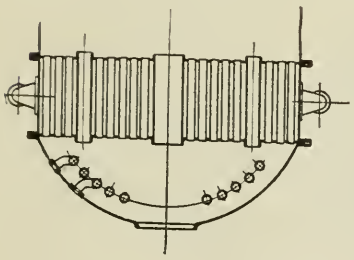


FIG. 7—CALANDRIA PAN.

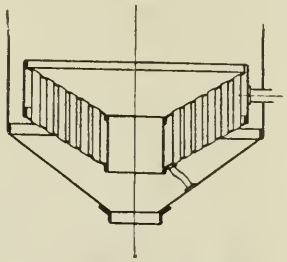


FIG. 8 — VACUUM PAN WITH INCLINED TUBE SHEETS

where more heating surface can be provided in a pan of given diameter than is possible with coils, exhaust steam can be and is often used instead of live steam. With exhaust steam the pressure will not be higher than about 10 lb. gage and the apparent temperature fall will be in the neighborhood of 100 deg. to 110 deg.

HYDROSTATIC HEAD

In vacuum pans the head is much greater than in evaporators. In a pan of average size the maximum head at the end of a strike is 12 ft. to 14 ft. above the lowest heating surface and a large part of the strike is boiled with average heads of 5 ft. to 8 ft. This, of course, results in a considerable increase of pressure and the temperature of boiling will be considerably higher than that corresponding to the vacuum in the pan. For this reason it is best to design vacuum pans with relatively large diameter and small height.

DENSITY AND PURITY OF THE LIQUID

In laboratory evaporator tests of Professor Kerr it was found that the density of the liquid also has a marked effect upon the rise in boiling temperature above the theoretical. For 70 deg. Brix, the rise about the theoretical was about 9.4 deg., with a vacuum of 25 in., referred to a barometer of 30 in. This curve was obtained with a sugar solution made up from a granulated white sugar, which was, therefore, practically pure—that is, with a purity of 100. The density of a strike varies from 50 deg. Brix at the beginning to about 95 deg. Brix at the end, so that the average Brix of a strike would be 70.

The purity of the liquid also affects the rise in temperature above the theoretical, the lower the purity the greater the rise. For Louisiana the purity of a strike of firsts will average something like 70, while for lower products the purity will be 60 or less. Sometimes a crystallizer strike will have a purity of considerably less than 50. In the tropics the purity will be somewhat higher than these, a purity of 80 for a strike of first being common.

Fig. 10 gives curves plotted from figures given by Classen showing the relation of purity to temperature rise. From this it is evident that due to the high density and low purity alone the temperature rise above the theoretical will be more than 25 deg. and in addition to this there is an added increase due to hydrostatic head, making a total rise of 30 deg. or more for the maximum condition.

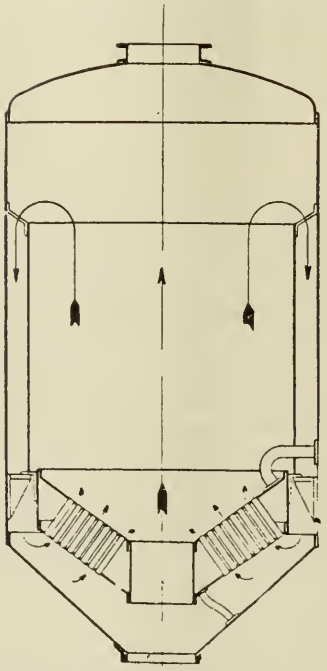


FIG. 9—EXPRESS PAN, INCLINED TUBES AND TUBE SHEETS.

THICKNESS AND MATERIAL OF THE HEATING TUBES OR COILS

As a usual thing, the diameter of coil in coil pans is 3½ in. or 4 in. The tubes in calandria pans also are usually 3½ in. to 4 in. in diameter. On account of the increased diameter, also on account of the more or less violent vibration incident to ebullition, the tubes are thicker than evaporator tubes, being usually in the neighborhood of 14 gage, corresponding to a thickness of approximately 1/12 in. This will cause some reduction in the heat transmission.

The heating surface in both coil and calandria pans is greater heat transmitting quality, but because of its ductility, which makes it easy to work. The latter is especially important in coil pans.

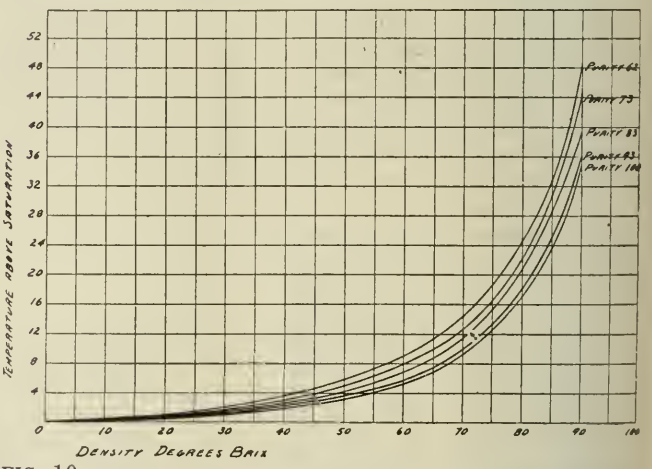


FIG. 10—EFFECT OF PURITY ON TEMPERATURE OF BOILING

VELOCITY OF CIRCULATION OF THE BOILING MASS

As in evaporators, rapid circulation is very beneficial as regards heat transmission. Much can be done in designing pans that will aid in bringing about good circulation.

In calandria pans the same general principles hold as with standard evaporators. Generally there is a central

downtake and in some cases additional downtakes, as shown in Fig. 7. The inclined tube sheets shown in Figs. 8 and 9 also aid in producing defined paths of circulation, the liquid passing upward through the tubes at the outside and in the annular space at the circumference and downward at the middle.

In order to further define the path of circulation above the calandria, the Express pan, Fig. 9, is provided with a cylindrical false shell, strengthened by pipes, *B*, which tends to give a circulation as shown by the arrows. The liquid inside of the false shell rising from the heating surface is of lower density than that between the false shell and the shell, due to the high temperature bubbles of vapor it contains. This causes the liquid to overflow from the interior to the exterior of the false shell. It is said there are two separate circulations as shown by the arrows.

In coil pans the path of circulation is likely not to be so positive or well defined as in calandria pans and for this reason the coefficient of heat transmission may be greater in calandria pans than in coil pans. The circulation is upward between coils and downward through the downtake at the center, the diameter of the downtake being equal to the minimum diameter of the coils. In a 10-ft. coil pan of standard construction the downtake will be in the neighborhood of 30 in. in diameter.

The space between coils in horizontal directions affects the circulation also. In placing the coils one above the other the space from bottom to top should be as straight as possible, otherwise the resistance to the flow of liquid in a vertical direction will be great and the rapidity of circulation reduced. The supports of the coils may also interfere with the circulation if they occupy too much room and are improperly arranged.

In some coil pans a circulation is induced mechanically by means of a revolving screw placed in the vertical axis of the pan.

VELOCITY OF STEAM

As in evaporators a rapid flow of steam on the heating surface will increase the coefficient of heat transmission. In calandria pans the same principles hold in regard to steam velocity and distribution as in standard effects. As vacuum pans seldom use steam of pressure below that of the atmosphere, pumps for removing the condensation are not required, hence the flow of steam toward a pump, which is common in evaporators, is missing in calandria pans. In coil pans the velocity of the steam is high at the end of the coil nearest the entrance and is practically zero at the other end, provided no steam is allowed to leave the coil, as would be the case when traps or automatic receiver pumps are used for removing the condensation. However, when adjustable check valves are used and they are left open too much, there will be some flow of steam from the coil, which will result in increased heat transmission, though this will be at the expense of economy.

AIR IN THE HEATING COMPARTMENT

The presence of air in the heating compartment has the same detrimental effect whether in vacuum pans or in evaporators. Air enters with the steam, and, as the steam condenses, it will accumulate unless it is promptly removed. On account of the relatively high pressure in the heating compartment of vacuum pans, the loss in temperature fall due to the presence of air is small as compared with evaporators where the pressures are in most cases below that of the atmosphere.

In calandria pans the methods of removing air are practically the same as for standard evaporators, vents being required. In connecting the pump or trap which removes the condensation from the calandria it is important to arrange the piping in such manner that air pockets will not be formed.

In coil pans the air is removed along with the condensation from the lower ends of the coils by different methods which will be described under the head of condensation.

Where traps are used, resulting in practically no steam velocity at the lower ends of the coils, there will be a tendency for air to accumulate and to vent this air numerous devices have been employed.

One requisite for the prevention of air pockets in coils or in the piping is that there should be a gradual incline downward where the pipe runs full of water. As air will rise in water, an air pocket will be formed at any high point unless the velocity is sufficient to sweep air bubbles along with the water.

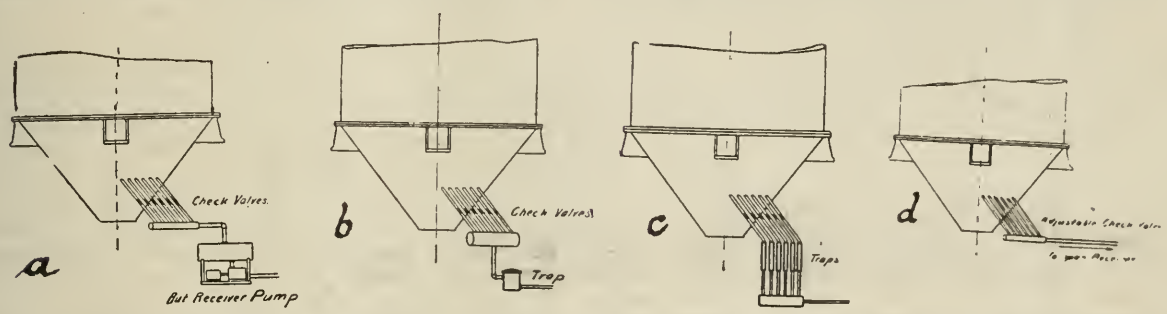


FIG. 11—DIFFERENT WAYS OF REMOVING CONDENSATION FROM VACUUM PANS; (*a*, BY AUTOMATIC RECEIVER PUMP; *b*, BY A SINGLE TRAP; *c*, WITH A TRAP FOR EACH COIL; *d*, WITH ADJUSTABLE CHECK VALVES)

CONDENSATION

As in all heating and evaporating apparatus vacuum pans must be promptly voided of the water of condensation or there will be a loss in the efficiency of the heating surface. The water of condensation may be removed from calandria vacuum pans by means of traps or automatic receiver pumps, either of which when properly installed and of the proper kind is satisfactory. The condensation from coil pans may be removed in a number of different ways as shown in Figs. 11, *a*, *b*, *c*, *d*.

Systems for handling condensation from heating and evaporating apparatus in sugar factories may be arranged according to two systems—namely, "closed" and "open." In the former the condensation is returned to the boiler as feed water without releasing the pressure —in other words, the boiler receives it at the temperature it had when leaving the pan or other apparatus. In the open system the water after leaving the pan or other apparatus is taken to an open receiver or hot well, from which it is pumped to the boiler. It is evident that as the pressure in the open receiver is that of the atmosphere, the temperature of the boiler feed taken from it cannot be higher than 212 deg. In vacuum pans the steam pressures are such that the temperature of the condensation may be 250 or more. When water with such high temperature is released in an open re-

ceiver a large amount of heat will pass off in the form of vapor when the pressure is released.

The arrangement shown in Fig 11a is well adapted for use with a closed system. The arrangement shown in Fig. 11b may also be used with a closed system, provided the trap is of the "return" type. In Fig. 11c separate traps are connected to the drain pipes for each coil, the traps being of the "non-return" type. In Fig 11d the removal of condensation is controlled by means of adjustable check valves. These valves are adjusted so that water but not steam will flow through. Evidently this arrangement could be used only with an open system.

On account of the occasional trouble due to the accumulation of air at different points in the system, to the disturbance caused by the mixing of condensation waters of different temperature, and to the fear that the feed pumps will not handle the water of very high temperature, there has been some objection to the use of closed systems. Practice, however, has shown that such systems are feasible and desirable, provided they are designed and arranged along rational lines. Often a closed system is lacking only in the need of equalizing or flash connections for ridding the system of air and vapors. The feed pumps will take water no matter how hot it is, if the pressure in the suction main is sufficient. Consider the water from a vacuum pan with a temperature of 280 deg. This high temperature is that corresponding to a pressure of 65 lb. gage and this pressure will certainly force the water into the pump, unless the pump happens to be too small for the work, so that it has to run at an abnormally high speed. In systems of this kind it is of great importance to have pumps of liberal size so that they can handle the water at slow speed.

Hot water mixing with cold water in a feed water heater is likely to cause pounding and unsteady action in general. For this reason it is better to mix them in a receiver of considerable volume with some vapor space in the upper part of it. The vapors forming in the top of the receiver may be released into the exhaust mains or into some heater where the heat from them may be utilized. To release these vapors into the atmosphere would, of course, make an open system of it.

Fig. 12 illustrates diagrammatically the feed water system used at the new Adeline sugar factory. There are four boiler feed pumps, three of which are of the automatic receiver type, the other without a receiver. There are two vacuum pans, the condensation from which is removed by two of these automatic receiver pumps. There are three raw juice heaters, though only two of them are in operation at one time, the third one being out for cleaning. One of these heaters operates with live steam and the other with exhaust steam. A large portion of the feed water naturally comes from these raw juice heaters. There are also two thin juice and two thick juice heaters, though only one of each is operated at one time under normal running conditions. Automatic receiver pump, number three, handles all of the condensation except that from the two vacuum pans. This includes condensation from the raw juice heaters, the thin juice heaters, the thick juice heaters, the steam engine separators, and the first bodies of the evaporators, also the drips from the high-pressure steam lines. Each of these different lines drain into a trap and the traps discharge through separate lines into the header above the receiver of pump number 3. The traps for the raw juice heaters are located on the ground floor below the level of the header, each trap having a live steam connection for discharging.

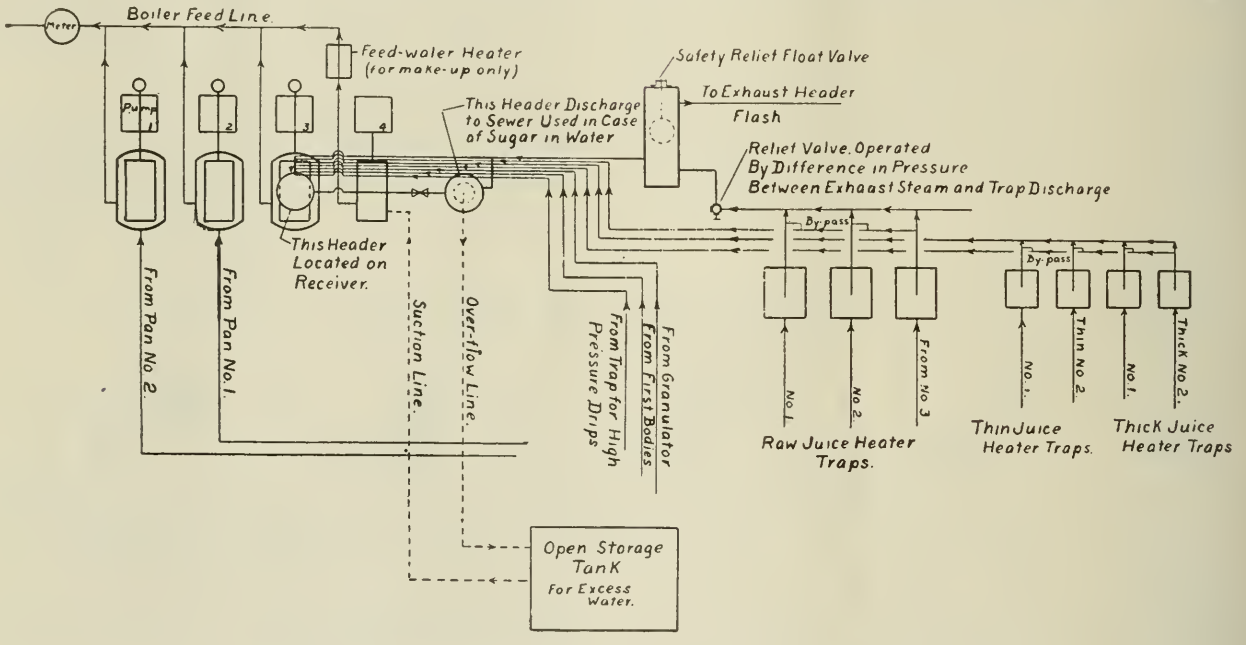


FIG. 12—SYSTEM FOR HANDLING CONDENSATION AT ADELINE SUGAR FACTORY

In order to provide for flash from the vapors coming from the condensation leaving the live steam raw juice heater a flash drum is provided as shown. The raw juice heaters are so connected that condensation from the exhaust heater can always be by-passed around the trap directly to the header. The condensation from the live steam heater passes through the relief valve into the flash drum and from there to the header, where it mixes with the condensation from other sources. From the top of this flash drum a flash connection is made to the exhaust steam mains. At one end of this drum there is an outlet with float-operated valve so that water cannot rise above a certain height in the drum. This prevents water from getting into the exhaust main. By means of this drum all disturbances of the kind mentioned above are prevented, the liberated flash being utilized along with the exhaust steam in the evaporators and other apparatus using exhaust steam. The make-up

feed water is handled by pump number 4, which draws from an open tank outside of the boiler room. The water in this tank is condensation coming from the second and third bodies of the evaporators. There is also an overflow into this tank from the header described above, which operates occasionally when the supply of condensation is greater than the boiler feed requirements at the time. This open tank in turn has an overflow into the sewer. The average temperature of feed water in this plant as found in a number of tests was about 216 deg. Fahr.

Fig. 13 shows another closed feed water system. In principle it is the same as that used at the Guanica Central in Porto Rico. In this case all of the condensation from different sources used for feed water is delivered to the boiler feed receiver, from which hand-controlled feed pumps deliver it to the boilers. The quadruple effects and the vacuum pans are situated some 40 ft. above the boiler feed receiver. From the top of the boiler feed receiver there is a vapor line connecting to the exhaust mains. In this line is a relief valve set at 15 lb. gage, so that there will be a pressure of 15 lb. gage in the receiver. The condensation from the vacuum pans is discharged by traps into an auxiliary closed receiver with a vapor connection to a feed water heater used for heating make-up feed water. The condensation is discharged by gravity into the boiler feed receiver. The condensation from live steam heaters is discharged by traps directly to the boiler feed receiver. As shown, the juice heaters using exhaust steam discharge their condensation by means of a trap to an open receiver. The pressure in the exhaust heaters is seldom much above atmospheric. The hot juice leaving the live steam juice heaters usually has a temperature of 220 deg.

On its way to the separators it is passed through eliminators, consisting in the main of closed drums with practically atmospheric pressure in them. The object of these eliminators is to remove and make possible the utilization of the heat in the juice above 212 deg. This heat passes off in vapors which mix with those from the auxiliary pan receiver and which are utilized in heating the feed water or in preheating juice just prior to the quadruple effects, also in heating scums in the mud tanks. This system works very satisfactorily, the average temperature of the boiler feed being about 227 deg. Fahr. There are no air locks and the system runs very smoothly.

The removal of condensation is also affected largely by the design of the vacuum pans themselves. The inclined tube sheets of Figs. 8 and 9 facilitate prompt drainage, the water being taken off from the lowest point. In large pans of this type there are generally three or four outlets.

In coil pans the length and diameter of the coil and its inclination to the horizontal has much to do with its drainage. With a coil of given diameter and steam pressure the amount of water that can flow out at its lower end is limited according to hydraulic law. Since the carrying-away capacity is proportional to the diameter, and the condensing power proportional to the length, the ratio of length to diameter is a controlling factor. It has often been stated that this ratio should not exceed 200.

Naturally a coil with steep inclination will drain better than a coil less steep—in fact, the steepness of the coil depends upon the length of coil in a pan of given size, a short coil giving a greater inclination than a long coil, equal drops considered. By reference to Figs. 1 to 4, inclusive, it can be readily seen that with a pan of given diameter a single coil would have approximately twice the length of a double coil, and four times the length of a quadruple coil, the angle of inclination being greatest in a quadruple, less in a double and least in a single coil. In pans of average size double coils are most common, quadruple coils being used in very large pans and single coils in very small pans.

Occasionally triple coils are used, branching on the inside in the manner similar to that shown in Figs. 1 to 4. Figs. 1, 2, 4 show two types of outlets for double coils. In the former there are two separate outlets—in other words, there would be a total of 12 outlets. In Fig. 1 the two coils are brought together with a single outlet so that there would be a total of six outlets. On general principles the double outlet arrangement is to be preferred. In the attempt to arrange for shorter coils the manifold coil pans shown in Figs. 5 and 6 have been designed. In Fig. 5 each manifold inside of the pan is divided into four

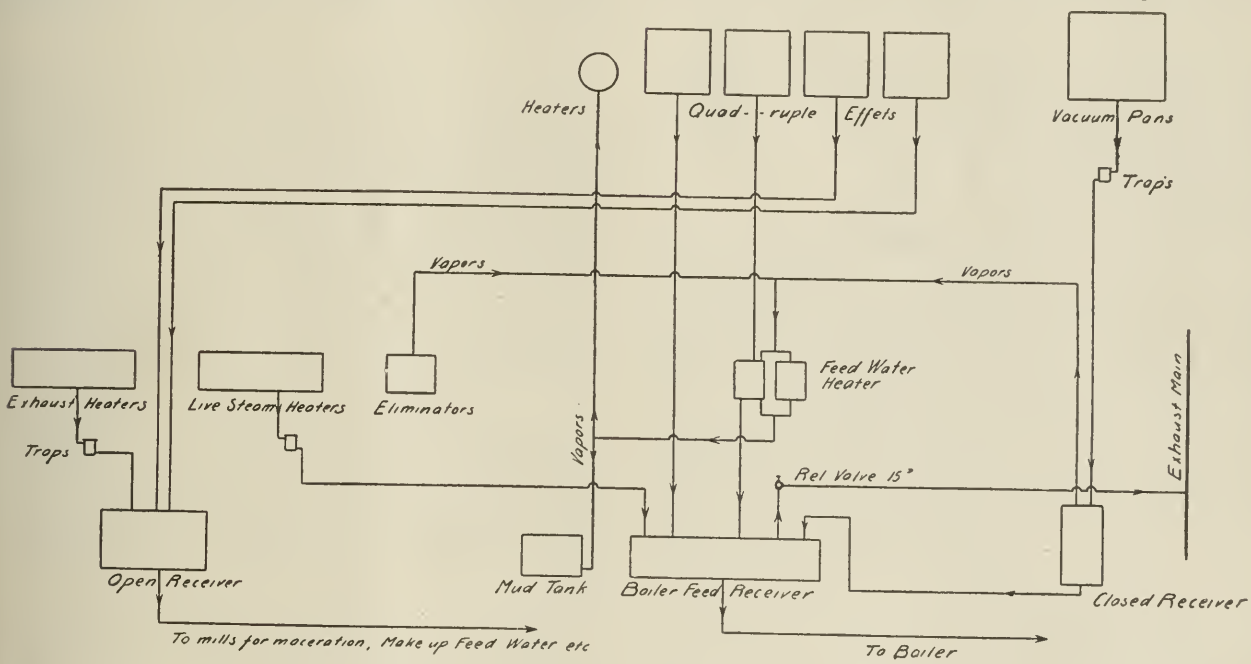


FIG. 13—SYSTEM FOR HANDLING CONDENSATION AT GUANICA CENTRAL

parts, so that steam makes a circuit through three coils, then two coils, then two circuits of one coil each, the condensation being led off from the lowest point of each manifold. As shown in Fig. 6, there is a steam manifold and a condensation manifold for each set of coils. The steam makes one circuit, no circuit being greater than the length of one coil.

DISTRIBUTION OF STEAM

Calandria vacuum pans differ from standard effects in that they seldom have circumferential distribution of steam. The steam is usually delivered directly to the tubes by the steam pipe which enters at one side. In very large pans the steam may enter in two pipes on opposite sides of the calandria. In coil pans the steam distribution depends entirely upon the location of the coils, the diameter of the coils and their distance apart. Naturally a better distribution can be obtained by making the coils small.

Some years ago a number of pans were built with two-inch coils, the spacing between coils being about two inches also. This was found to be an advantageous arrangement as regards heat transmission, but very objectionable as regards voiding the pan. With very stiff masscuite the pan could not be voided.

In modern coil pans in which the coils are usually 4 in. in diameter the spacing is generally about equal to the diameter of the coils—that is 3½ to 4 in.

FACTORS AFFECTING ECONOMY IN VACUUM PANS

The heat efficiency of vacuum pans depends altogether upon the loss due to radiation. However, the weight of steam required per unit weight of water evaporated is affected by the following factors:

Loss due to radiation.
Temperature of the syrup entering.
Pressure of the steam.
Temperature of condensed steam leaving.

In all vacuum pans the heating elements are surrounded by the boiling liquid which has a relatively low temperature—that is, the temperature corresponding to the vacuum under which the boiling takes place. The temperature drop from inside to outside is, therefore, small, hence the radiation loss should be small.

The amount of this loss will, of course, depend upon whether the radiation surfaces are covered with heat insulation or not and upon the kind of covering used. An approximate calculation of Professor Kerr shows 0.6 per cent loss for a 10 ft. coil pan boiling under normal conditions without covering, 0.15 per cent when entirely covered and 0.36 per cent with the cylindrical part of the shell covered, the dome and catch-all being uncovered. In each case the loss is based on the total heat delivered in the steam.

Naturally the radiation loss will be less for a strike of given size when it is boiled quickly than when boiled slowly. For this reason pans are usually less efficient from the heat standpoint when boiling low grade products than when boiling high grade products. Calandria pans with their greater amount of heating surface and more rapid circulation should be more efficient thermally than coil pans because of the shorter time required to boil.

The work of a vacuum pan consists of two parts—namely, heating the entering syrup up to the boiling point and evaporating. Naturally the lower the temperature of the syrup entering the more steam will be required for heating it up to the vaporization point.

The pressure of the steam and the vacuum affect the weight of steam required per pound of water evaporated due to the effect of latent heat. For example, assume a steam pressure of 60 lb. gage with corresponding latent heat of 899 and a vacuum of 26 in., with corresponding latent heat of 1026. In this case $1026 \div 899 = 1.085$ lb. of steam will be required to evaporate 1 lb. of water from the juice in addition to that required for heating. With high steam pressure a larger weight of steam would be required due to the reduced latent heat, and vice versa.

In calandria pans there may be a small loss in venting the incondensable gases, though this will be practically negligible. In coil pans there may be a considerable loss due to leakage of steam, especially where check valves are used and the steam is allowed to blow through to the atmosphere. Pan operators like to do this, because the current of steam thus set up in the coils results in increased heat transmission and capacity. It is evident, however, that this can be done only at the expense of economy. The same result may be brought about by leaky traps. It has been found in practice that much attention has to be given to traps to prevent the valves from leaking, especially if they are not of the best construction. Unfortunately, it is difficult to determine these leakage losses by tests for the reason that the steam thus lost cannot be measured, the steam consumption being determined by weighing the condensation. If the condensation is removed immediately after it forms, its temperature will be practically the same as that of the steam before it condenses. If it remains any length of time after condensing, its temperature will be reduced and this will result in decreased steam consumption for a given amount of evaporation.

Tests of Vacuum Pans

A very extended series of tests were made by Professor Kerr and his co-workers with a view of obtaining data regarding heat transmission and economy under regular operating conditions, for different types of pans, with varying grades of product. Twenty-three pans were tested in all. As to the arrangement and details of the tests the reader must be referred to the original publication. (An interesting account of a vacuum pan test of this kind with heat balance was given in an article specially written for this journal by Professor Kerr, in our issue of February, 1914, Vol. XII, p. 81.)

COEFFICIENT OF HEAT TRANSMISSION

The capacity of a given vacuum pan will depend upon the coefficient of heat transmission, the time the heating surface is on in per cent of the total time of boiling the strike and upon the temperature fall, the latter being affected materially by the increase of boiling temperature due to head and density, etc., which has been discussed.

The ability of the heating surface to transmit heat from steam to boiling liquid is directly proportional to the coefficient of heat transmission. It was calculated by dividing the total heat transmitted by the actual temperature difference and by the average time the total heating surface was working. The actual temperature fall was obtained by subtracting the temperature of boiling from the temperature of the steam.

In making the tests careful data were kept regarding the time when steam was turned on each coil, so that the actual time each coil was working could be estimated. The sum obtained by adding the time the coils operated, divided by the number of coils, gave the average time the total heating surface operated. This divided by the time of a strike and multiplied by 100 gave the actual time of the total heating surface in operation in per cent of the total time of the test. Evidently it would not be fair to charge the heating surface with the total time of the strike. The average time the total heating surface was on varied from 56 per cent to 83.9 per cent of the time of the strike, the average being 76 per cent.

This shows the great variation in capacity which may result from different methods of handling steam in the different coils as practiced by different sugar boilers.

Figures are given of the apparent and actual weight of water evaporated per square feet of heating surface per hour, the apparent weight being based on the total time of the strike in each case, and the actual weight on the actual average time the heating surface was working. The apparent weight of water evaporated varied between 6.48 and 20.35 lb. per sq. ft. per hour, the actual weight between 9.55 and 27.3 lb. But even the actual weights of water evaporated are not a fair unit for comparison because the steam pressure and the vacuum varied in the different tests. Thus, after all, in these tests the coefficient of heat transmission is the only fair and absolute measure of the heat-transmitting ability of the heating surface.

The figures for the coefficient of heat transmission (in B.t.u.'s transmitted per square foot of heating surface per hour per degree Fahrenheit difference in temperature of the two sides of the heating surface) varied in the different tests between 45 and 174.8. The average coefficient for the coil pans with straight strikes, omitting tests 19 and 20, is 110, varying from a minimum of 76.28 to a maximum of 174.8. The average time since cleaning was three days—in fact, in nearly all cases the heating surface may be considered to have been in fairly good condition. The best three tests on coil pans—namely, 21, 22 and 23—gave coefficients of 134.5, 124.3 and 174.8 respectively—in fact, these were much higher than the others and raised the average considerably. Without them, the average coefficient would have been 95. These three tests represent the three principal methods for removing condensate—namely, check valves with single trap, automatic receiver pump and adjustable check valves. The high coefficients obtained with these different arrangements show that either of them when properly installed and operated will give good results.

The highest coefficient, 174.8, was obtained with the shortest average length of coil—that is, with a ratio of 118. Doubtless this has much to do with the fine result obtained. Tests 21 and 22 also were made on pans with relatively short coils, which were well drained and in which the heating surface was clean. With so many varying conditions, the effect of some of which it was impossible to measure, it is impossible to form definite conclusions as to the varying results obtained in the different tests. The highest ratio of length to diameter of coil was 294. Although there is no definite relation between this ratio and the coefficient of heat transmission it is evident that the length of the coil had much to do with the variation of the coefficients obtained.

Tests 1, 2 and 3, giving heat transmission coefficients of 111, 88.3 and 45 respectively, were made with straight, mixed and crystallizer strikes with greatly varying purities and give some very conclusive and interesting data regarding the effect of varying kinds of product upon the coefficient, since these three tests were made upon the same pan and under conditions practically the same.

TEMPERATURE OF BOILING

The increase of boiling temperature due to hydrostatic head, density of liquid, and purity of liquid, has been discussed before. In these tests the temperature rise varied from a minimum of 11.9 to a maximum of 27.5 deg., the average being 19.7 deg. The minimum rise was obtained with the Express pan (Fig. 9), and the maximum with a 10-ft. coil pan. The average temperature rise in the three tests on the Express pan was only 12.9 deg., which is considerably less than that obtained in the coil pans. This is doubtless due to the reduced height of pan, also to the better circulation. At the beginning of a strike both the hydrostatic head and the density were smaller than at the end of the strike, there being a gradual increase from beginning to end. Naturally, therefore, the temperature rise of the boiling point increases toward the end of the strike.

Curves given in a diagram of the report show very clearly the effect of purity upon the temperature rise, the rise at the end of the test being 20.5 deg. for the straight strike, 27½ deg. for the mixed strike and 31 deg. for the crystallizer strike. The capacity of a pan decreases with the purity, not only because of the low coefficient of heat transmission, but because of the reduced temperature fall due to rise of the boiling point as well. In each of the curves there is a gradually increasing distance between the curve representing temperature of boiling and that representing temperature corresponding to vacuum.

COIL VS. CALANDRIA PANS

From the data given in the report it will be seen that the average coefficient of heat transmission in the Express pan tests was 40 per cent greater than the average coefficient in coil pans. The rise in temperature of boiling due to hydrostatic head, density and purity was also shown to be less in an Express pan than in the coil pans, which is also an advantage in that the smaller the temperature rise the greater the temperature fall for a given steam pressure. This means, of course, that there is a corresponding increase in capacity.

It may be well to state also that the amount of heating surface in the Express pan tested could be doubled by placing another calandria above the existing one. This, however, would require increasing the height of the pan.

The greater coefficient of heat transmission in the Express pan is doubtless due to the more rapid circulation and the more efficient removal of condensation, the latter being due partly to the sloping tube sheets and inclined tubes.

The test on the plain calandria pan shows a coefficient of only 58.38, which is very poor. This test was made with good syrup, but with steam having a pressure only slightly above that of the atmosphere. The reason for the very low coefficient is probably in the fact that the calandria was not properly voided of condensation. The condensation was removed by means of a steam pump; the outlet for condensation was 1½ in., though this was reduced to ¾ in. This is evidently too small. For these reasons the results of this test can not be taken as representative of the type.

RATE OF VAPOR FORMATION

Designers of vacuum pans and accessory apparatus frequently need information regarding the rate at which vapor is formed in vacuum pans during different intervals of time in the boiling of a strike. Such data are of especial value in calculating the dimensions of condensers and vapor pipes. Some tests were made with this problem in view.

At first thought it would seem that the rate of steam condensation would be sufficient for this purpose. It should be remembered, however, that part of the steam condensed is used for heating and a curve plotted with time against rate of steam condensation might not have the same shape, as one with time plotted against water vaporized.

In order to determine the weight of water evaporated during successive time intervals of a strike it was found necessary to measure the weight of the hot well water. This was done by means of a weir in connection with a Hook gage. Knowing the weight of water for each successive interval of time the heat delivered to it during that time could be determined from its initial and final temperatures. This, divided by the heat of vaporization corresponding to the vacuum in

the pan for that interval, gives the weight of water evaporated.

This method was carried out in one test and the result, plotted diagrammatically, shows that for all practical purposes it may be assumed that the rate of vapor formation is proportional to the rate of steam condensation. As the curve in question is practically a straight line, the rate of steam formation during successive intervals is practically the same as the average rate—in other words, the velocity of vapors in a coil pan may be assumed to be the same at all times during a strike.

HEAT BALANCE

Finally the steam consumption was measured in eight of the tests and the heat balance determined for the same tests. There is some uncertainty in the heat-balance calculations on account of the fact that the figures for specific heats of sugar solutions, used in the calculations, are uncertain. The total heat entering, minus the heat leaving in the condensed steam is termed the "available heat." The heat actually used in evaporation, divided by the available heat and multiplied by 100, is designated as efficiency.

The efficiency figures vary from 90.9 to 96.95 per cent, with the exception of one test in which it comes out as more than 100 per cent. The results of these tests do not show any difference in economy for coil and calandria pans.

It was thought that the temperature of the condensed steam leaving might be nearer that of the steam in calandria pans than in coil pans. Observations, however, seem to show practically no difference in this respect.

An average from three tests on the Express pan showed a temperature of condensate 15.3 deg. lower than that corresponding to the steam pressure. The average temperature of condensate from coil pans was 16 deg. less than that corresponding to the steam pressure and varying from 11.7 deg. to 21.3 deg.

Vanadium from Oxide to Steel

BY WARREN F. BLEECKER AND WALTER L. MORRISON

The ores from which ferrovanadium is produced and the processes of extracting the vanadium salts and oxides therefrom are so generally known that it is unnecessary to discuss them here. They are only of importance in determining the cost of raw oxides or vanadium salts and the cost in every case would be independent of the method of reduction.

The processes of making ferrovanadium from the raw salts and oxides are limited, and there are but two known reducing agents which may be used for the production of ferrovanadium on a commercial scale: aluminium and silicon.

Aluminium is the one most used and is the less desirable. Any process wherein aluminium is used as a reducing agent for vanadium is but a variation of the Goldschmidt thermit process.

When the aluminothermic process is carried on strictly as an exothermic reaction, there is one certain evil, and the choice of one of two others. First, the quantity of aluminium necessary for reduction is much greater than the theoretical amount. Secondly the recovery of vanadium will either be low or there will be found too much aluminium in the resulting alloy. A further objection to this process is that there is no opportunity for refining the alloy, in case there are objectionable elements present.

These difficulties may be done away with by carrying the reaction on in an electric furnace. The raw oxide or vanadate may even be partially reduced with carbon before the final treatment with aluminium and by properly treating the reduced alloy with slags, the refining may be carried to any required degree. It is, of course, understood that if the impurities are base metals there is no hope of removing them in the electric furnace.

The better process of making ferrovanadium is by reduction with silicon. Silicon may be had at a cost of about one-third that of aluminium and its theoretical oxygen value is higher by 25 per cent. In heat units the advantage is with aluminium.

The reaction between vanadium pentoxide and silicon is not quite self-propagating. In the electric furnace, however, the reaction is very brisk and very satisfactory.

As with aluminium, it is not possible to obtain at the same time and in one operation a high vanadium recovery, high silicon efficiency and a low silicon content in the resulting alloy. In two electric-furnace operations these three very desirable conditions may be had at a very small additional expense. We have never succeeded in doing this in one operation, although if an alloy containing 4 or 5 per cent of silicon were desired only one operation would be necessary.

In the commercial application of vanadium to steel there are several factors which determine the cost and to a large extent the cost of the contained vanadium in steel determines what classes of steels will stand the expense of the vanadium addition.

The important factors in determining the cost of vanadium per ton of steel is as follows:

The cost of the raw ore per pound of vanadium contained.

The cost of the raw oxide per pound recovered.

The grade and character of the raw oxide.

The cost of reduction per pound of vanadium recovered.

The efficiency of the reduction process.

The efficiency of the alloy added to steel.

In our present discussion we are not concerned with the first two items. They are of the utmost importance, but they are constant factors whatever the subsequent procedure.

The grade and character of the raw oxide is important, because, as will appear later, the presence of base metals, such as iron, will be a source of greater expense in one case than in the other.

The efficiency of the aluminium thermit process is known only to those who are using it on a large scale. The best we have been able to do under the most favorable conditions, and using a good grade of oxide, is around 70 per cent recovery. Under these conditions there will remain in the finished alloy between 1 and 2 per cent Al.

Using the electric furnace the efficiency may be raised to 90 per cent recovery with 1.2 lb. Al per lb. V recovered. The resulting alloy will contain what we call a trace of aluminium, under 1 per cent carbon and less than 2 per cent silicon.

Using silicon as a reducing agent, the efficiency will be about 85 per cent recovery, with 1.25 lb. Si per lb. V recovered. The resulting alloy will contain less than 0.30 C., trace of aluminium, and 4-5 per cent Si. This silicon may be brought under 1 per cent by a second operation.

The reduction cost per pound V recovered we are at present not at liberty to divulge, but with furnace upkeep, electrode consumption, energy, fluxes, labor, overhead, etc., while very heavy, it still allows a very great saving over processes of reduction in which electric energy is not used.

The recovery of vanadium from ferrovanadium to finished steel castings probably averages 70 or 75 per cent.

If we assume all of the above data to be correct we may arrive at the average recovery from the raw oxide to the steel and knowing the market price of vanadium we may determine the cost per pound V in steel.

Taking the average efficiency of silicon reduction by multiplying by 0.75, we arrive at the value 63.75, which means that the higest recovery we may expect is in the low sixties.

This value further means that a pound of vanadium in steel requires one and two-thirds pounds of vanadium as oxide, and at a value of $2 per pound as alloy, costs $2.66.

Vanadium pentoxide contains 56 per cent metallic vanadium. One pound of vanadium in steel, therefore, required 2.96 lb. of oxide, which 15 per cent was lost in reduction, and over 20 per cent lost in the addition to steel.

It is evident, therefore, that if vanadium oxide could be added directly to steel, with a high efficiency, the cost of reduction and the loss in efficiency might be greatly reduced with a benefit to both the alloy manufacturer and the steel maker.

Vanadium may be introduced directly into steel, cast iron or any ferrous alloy from the pentoxide. The method of doing this is very simple and economical, and as will be seen by referring to the analytical data the recovery is excellent.

If a quantity of a vanadium compound, such as calcium vanadate, be thoroughly mixed with a small quantity of iron scale and sufficient silicon to allow an excess of 10 per cent above the theoretical quantity, there will result a mixture, which when added to molten steel, will introduce vanadium into steel efficiently and without appreciable segregation.

Any vanadium compound may be used instead of calcium vanadate and aluminium may be used instead of silicon.

Upon further consideration of this reaction several very desirable advantages will be apparent.

Although, as stated above, the reaction between vanadium pentoxide and silicon is not self-propagating, it is exothermic. The only heat necessary, therefore, is that required to fuse the lime which is added to insure a complete separation of the reduced vanadium from the resulting slag. The addition of vanadium in this manner, so far as chilling the metal is concerned, is equivalent to adding alloy in the molten state.

It is possible in this manner to provide an additional agent of absolute uniformity, not only in grade, but in composition as well.

This exothermic mixture may be added to all classes of ferrous metals at any stage, with the assurance that the vanadium will be effective and will be uniformly distributed throughout the metal.

The electric furnace is particularly useful in carrying on this reaction, the recovery being as nearly perfect as it is possible to hope for.

It is not necessary to carry on any subsequent slagging operations and the vanadium mixture may be added without removing or otherwise disturbing the slag or any other normal working condition.

In certain alloys, as with many crystalline substances, the solution takes more readily at the time of the formation of the compound than after the compound has cooled and assumed a solid state. This condition apparently exists upon addition of the exothermic vanadium mixture to steel, with the result that a high vanadium recovery and a uniform distribution of vanadium takes place.

The melting point of vanadium alloys varies with several things outside of the vanadium content. The presence of carbon raises the melting point rapidly, while alminium and silicon tend to lower it.

In adding this exothermic vanadium mixture to the open hearth, the amount of silicon can be increased to take care of the iron oxide. In this case the iron oxide may be wholly or in part omitted from the mixture, since the function of this material is to afford a medium in which the vanadium is instantly soluble—otherwise the reduction would be very incomplete and the recovery low. The oxide of iron is simultaneously reduced and a very rich vanadium alloy is formed, which is further dissolved throughout the molten steel.

On the other hand, in crucible melting the quantity of silicon may be decreased on account of the highly reducing conditions which exist at the time of the addition.

An examination of the results obtained when treating cast iron will reveal the fact that the reaction begins at a relatively low temperature.

Some interesting results were obtained while experimenting with aluminium as a reducing agent in the exothermic mix.

The reaction proceeded with more violence than when silicon was used, as might have been predicted. The resulting slag, which was high in alumina, was not sufficiently fluid at the temperature of the molten iron and consequently did not allow the vanadium to act as efficiently as it would otherwise have done.

The metal was poured from the cupola into a 600-lb. ladle, the alloy added and the iron poured. The metal to which the aluminium was added purged badly from every flask, large and small. The plain metal did not purge, nor did that to which the silicon mixture was added.

The addition of vanadium to cast iron in the ladle did not seem to give the castings any additional strength or other desirable properties, although no physical tests were made upon the bars.

Vanadium added to cast iron melted in the electric furnace, the silicon mixture being used, gave the bars a very dense structure, while the strength and hardness were apparently unaffected. No tests were made beyond breaking the bars.

MATERIALS

The following materials were used in making the exothermic mixes:

Calcium vanadate,	24.3	per cent	V_2O_5
Vanadium oxide,	83	per cent	V_2O_5
Iron scale,	70	per cent	Fe.
Aluminium,	99	per cent	No 30 shot.
Silicon,	85	per cent	Si.
Lime,	85	per cent	CaO.

Mix A.

10 lb. calcium vanadate.
4.7 " aluminium.
10 " vanadium oxide.
1 oz. mix = 0.243 oz. V, or 0.0152 lb. V.
1 lb. mix = 0.243 lb. V.

Mix B.

10 lb. calcium vanadate.
9.2 " silicon.
10 " vanadium oxide.
1 oz. mix = 0.206 oz. V, or 0.0128 lb. V.
1 lb. mix = 0.206 lb. V.

Mix C.

100 lbs. iron scale.
21.4 " silicon.
1 lb. mix = 0.573 lb. Fe, or 9.2 oz. Fe.

The following steels were made in a small arch furnace lined with magnesite. In each case the boiler punchings were used, these being melted under a neutral slag.

The chromium was added as 60 per cent ferrochromium, the silicon as 85 per cent ferrosilicon and the manganese as 50 per cent ferromanganese.

With but one or two exceptions the steels poured quietly, without purging and the castings were apparently solid.

The vanadium mixture should be added to the electric furnace just before pouring into the ladle in order to get the best efficiency. In pouring larger quantities of steel it is probable that the vanadium could be added in the ladle, although if added in the furnace we are more certain of avoiding segregation.

In case the vanadium silicon mixture does not contain iron oxide, segregation takes place to such an extent that the analyses are not dependable.

100 lb. steel, 5 lb. chromium, 1 lb. 15 oz. silicon, 6 oz, ferromanganese, 4 oz. ferrosilicon, with 19 oz. Mix B and 7 oz. Mix C, yielded steel A 800, containing 0.36 V, 1.19 Si, 1.53 Cr, and 0.70 Mn.

100 lb. steel, 4 oz. ferrosilicon, 6 oz. ferromanganese, 1 lb. 10 oz. ferrochromium with 19 oz. Mix B and 7 oz. Mix C yielded steel A 803, containing 0.08 V, 0.09 Si, 0.92 Cr, and 0.18 C.

100 lb. boiler punchings, 4 oz. ferrosilicon, 6 oz. ferromanganese, with 19 oz. Mix B and 7 oz. Mix C yielded steel A 804, containing 0.20 V, 0.07 Si, 0.10 Cr. and 0.19 C.

100 lb. steel, 1 lb. nickel, 5 oz. ferrosilicon and 4 oz. ferromanganese, with 19 oz. Mix B and 7 oz. Mix C yielded steel A 806, containing 0.08 V, 0.28 Si, and 0.25 C.

50 lb. steel with 11 oz. vanadium-aluminium-thermit (0.3 V) (thermit in cartridge) yielded steel A 1086, containing 0.29 per cent V.

100 lb. steel, 1 lb. silicon (50 per cent), ½ lb. manganese (80 per cent) and 19 oz. Mix B gave A 1193, containing 2.4 per cent Si and 0.29 per cent V.

100 lb. steel turnings, 1 lb. silicon (50 per cent), ½ lb. manganese (80 per cent) with 19 oz. Mix B and 7 oz. Mix C gave A 1195, containing 1.10 per cent Si and 0.28 per cent V.

100 lb. boiler punchings, 3 lb. 12 oz. nickel, 6 oz. ferromanganese, 4 oz. ferrosilicon and 1 lb. 13 oz. ferrochromium, with 19 oz. Mix B and 7 oz. Mix C, gave A 794, containing 1.32 per cent Cr, 0.20 per cent C and 0.33 per cent V.

100 lb. steel, 6 oz. ferromanganese, 4 oz. ferrosilicon, with 19 oz. Mix B gave A 798 containing 0.22 per cent V.

100 lb. boiler punchings, 4 oz. ferrosilicon, 6 oz. ferromanganese, with 10 oz. Mix B, and 7 oz. Mix C and 1 lb. 10 oz. ferrochromium (67 per cent Cr.) gave A 802 containing 1.31 per cent Cr., 0.22 per cent C, 0.19 per cent Si, and 0.23 per cent V.

50 lb. cast-iron scrap, with 8 oz. Mix B and 4 oz. Mix C, gave A 1090, containing 0.09 per cent V.

50 lb. cast-iron scrap, with 8 oz. Mix B and 4 oz. Mix C gave A 1091, containing 0.11 per cent V.

50 lb. cast-iron scrap with 4 oz. Mix B and 2 oz. Mix C gave A 1088, containing 0.23 per cent V.

50 lb. cast-iron scrap with 4 oz. Mix B and 2 oz. Mix C, gave A 1089, containing 0.18 per cent V.

Cast-iron bars made at Washington, Pa.:

A 1092	0.048% V	2.14% Si
A 1093	0.032	2.32
A 1094	0.027	2.26
A 1095	0.03	2.11

Charges A-1088 and A-1089 were made in the eletcric furnace and the vanadium added before pouring the cast iron into the ladle. It will be seen in this case that the efficiency is very high.

The samples A-1092 to A-1095, inclusive, were the result of adding the vanadium mixture to cast iron in a 600-lb. ladle, as the metal came from the cupola. It will be seen that while the efficiency is very low the temperature of the cast iron was sufficient to ignite the vanadium mixture and cause the reaction to proceed.

It must be concluded that vanadium may be added to steel, in the form of oxide, when mixed with a proper reducing agent and slagging elements.

It is further apparent that this process will result in the saving of the cost of reducing the vanadium in the production of the ferro-alloy.

Starting with a given quantity of oxide, we may expect, by this process, to find more vanadium in the steel than in case we introduce the intermediate step of making ferrovanadium.

American Electrochemical Society

The San Francisco meeting of the American Electrochemical Society will be held from Thursday to Saturday, Sept. 16 to 18, 1915. Friday, Sept. 17, will be devoted to joint sessions in the morning with the American Institute of Mining Engineers and in the afternoon with the American Institute of Electrical Engineers.

American Chemical Society

The next meeting of the American Chemical Society will be held at Seattle, Wash., from Monday to Thursday (Aug. 30 to Sept. 2). The schedule of the special train was given on page 419 of our July issue. The headquarters at Seattle will be at Hotel Frye, corner Third avenue and Yesler Way.

On Monday night, August 30, the council dinner will be held.

On Tuesday morning the first session will be opened by an address of welcome by Henry Suzzalo, president of the University of Washington, followed by the response by Charles H. Herty, president of the American Chemical Society. Dr. Leo H. Boekeland will then lecture on Chemical Industry, and Dr. H. K. Benson will speak on Industrial Resources and Opportunities of the Pacific Northwest.

In the afternoon the symposium of the Industrial Division, devoted to the influence of chemistry in various industries (which had been begun at the New Orleans meeting) will be completed. Papers will be presented by G. W. Sargent and A. S. Cushman, on iron and steel; by Alvis von Isakovics and E. T. Beiser, on perfumery; by G. W. Thompson, on lead; by Maximilian Toch, on paints and varnishes; by David T. Day, on petroleum, and by Sidney Mason on illuminating gas. A symposium will also be held on wood distillation.

In the evening a complimentary smoker will be given by the Seattle Commercial Club.

On Wednesday division meetings will be held during the day, and in the evening Dr. Charles H. Herty will present his presidential address.

For Thursday an excursion on Puget Sound is scheduled, and for the evening a subscription dinner.

The **Tyneside Alloys Co., Ltd.**, is a new British company operating at Pelaw, Newcastle-on-Tyne, for the manufacture of tungsten and molybdenum powders. The plant is open to purchase and treat all kinds of stanniferous tungsten ores and leady bismuth-molybdenum ores. The plant is under the management of Mr. William Jones, who formerly represented Mr. John Hays Hammond in Brazil.

Blast-Furnace Plant Auxiliaries and General Arrangement

BY J. E. JOHNSON, JR.

(*Concluded from page* 439)

The General Arrangement of Furnace Plants

In early days blast furnaces were very generally built singly, plants of two were scarce, and a greater number than that in charcoal practice were almost unknown. But as the world's consumption of iron has gone up the number of furnaces per plant has increased almost as rapidly as the tonnage per furnace, there being two in the United States with eleven, many of six and seven, and probably only a small portion of the total furnaces are single furnace plants. This fact has modified the general design of plants fundamentally. It is obvious that when a furnace stands alone the different elements of the plant as a whole may be arranged in almost any relation to one another, but when two or more are grouped together it is plain that their raw materials should come in by a means of transportation common to all, and that their output should be similarly taken away. Also that labor can be saved by grouping certain components of the equipment of each furnace together, notably the blowing engines, boilers and stoves. The first two can be supervised by the same men, and the third sometimes is. In considering the arrangement of furnace plants, therefore, we need scarcely to consider plants of less than two furnaces, because as stated above the equipment of the single furnace can be arranged in almost any reasonable way and meet the conditions fairly well.

On account of the enormous quantities of materials handled it is obvious that the best possible arrangement of the railroad tracks must be at the basis of any proper design, and all multiple furnace plants for many years past have virtually had the stock houses for all the furnaces in common, all being served by the same set of tracks. These for obvious reasons are made straight except in rare circumstances, and should always be so. This virtually forces the furnaces to be built in a straight line parallel to these stock house tracks.

The next points in the design involving the handling of a heavy tonnage of material are the casting arrangements and the cinder pits, and here it took us many years to reach a sensible design. Probably the greatest defect of all our designing is a tendency to put every part of the design either at right angles with or parallel to the next element, and plants have in general been laid out with their parts at right angles with or parallel to the other parts. The fact which seems to have escaped observation is that railroads do not run around right angles, and therefore with one part of the plant at right angles to another if the first were parallel with the tracks, the second must be at right angles to them, and therefore relatively inaccessible. In spite of this the line of the cast house was for many years built at right angles with the line of the stock house tracks, and in order to bring cars alongside the cast house to permit the direct loading of pig iron these tracks all had to make a sharp right angle turn. What is even worse is that, as the curves practically must all be laid down from the same direction they could turn to a tangent along the near side of the cast house wall, but could only approach it with great difficulty on the far side, a very disadvantageous condition.

A little careful consideration will show that there is no fundamental reason why the cast house should be at right angles to the stock house tracks, and when the first pair of Lorain furnaces were built an attempt was made to evade this difficulty by turning the cast houses toward one another, so making them parallel to instead of at right angles to the stock house tracks. This somewhat increased their accessibility, but took up much room, since obviously the two furnaces were more than the length of both cast houses apart.

Various modifications of the right angle plan were used, but without reaching any design which met the conditions satisfactorily. When designing the plant of the Federal Furnace Company of Chicago, Julian Kennedy adopted a plan which will undoubtedly be more and more used, though often in modified form, as time goes on. Fig. 11 shows a ground plan of these works on which the names of the different parts are clearly marked so that the arrangement is easily comprehensible. It is obvious from this plan how easily all parts of the plant are reached by railroad tracks with short and easy curves, and it will be equally obvious on a little reflection that if the cast houses had been placed at right angles to the line of the stock house trestles, in the old-fashioned way, their four sides in particular would have been almost inaccessible to railroad tracks within the yard limits available.

A further development of this idea took place when the Gary plant of the Indiana Steel Company was designed. A small scale plan of this plant reproduced from "The Iron Trade Review" is shown at Fig. 12. The scale is so small that some study is necessary to distinguish the different parts, but this can be done with a little pains.

In this case the cast houses were turned to an angle of about thirty degrees with the center line of the row of furnaces. The angle of the skip was made flatter and the base of the skip bridge further from the base of the furnace than in the Federal design so that tracks could be run along between the under side of the skip bridge and the foundation of the furnace itself, which greatly increases the accessibility of all parts of the plant to railroad tracks. These tracks underneath the skip communicate with the other tracks in front of the furnace by ladder tracks between every second pair of furnaces which run through diagonally on the same angle as that of the cast houses. These tracks serve not only the cast houses, but the dust-discharges of the different dust catchers as well. In this case each pair of furnaces becomes a lozenge shaped island in a wide river of tracks, with practically every part of the plant within easy reach of at least one track. It is seldom wise to prophesy finality in any technical matter, but the general principle of this design is so nearly perfect that it seems likely that it will eventually come to be the only plan considered for multiple furnace plants, but, of course, modifications to suit individual conditions or changes in the component parts of the plant may be made in every case.

The Distance of the Furnaces Apart

This is controlled by various circumstances. When the ore supply for the large part of a year has to be stocked that becomes one of the controlling factors because the cost of ore bridges increases very rapidly with their length, and commercially their practical length is limited on this account, as also by the great time required to traverse the trolley from one end to the other of a long bridge. The height of the ore pile is limited by considerations affecting the cost and strength of retaining walls at the sides of the stock pile, and the slope which the ore takes running back from them. The pile is thus limited in two dimensions, and in order to store a given tonnage of ore the required volume must be obtained by making the length of the

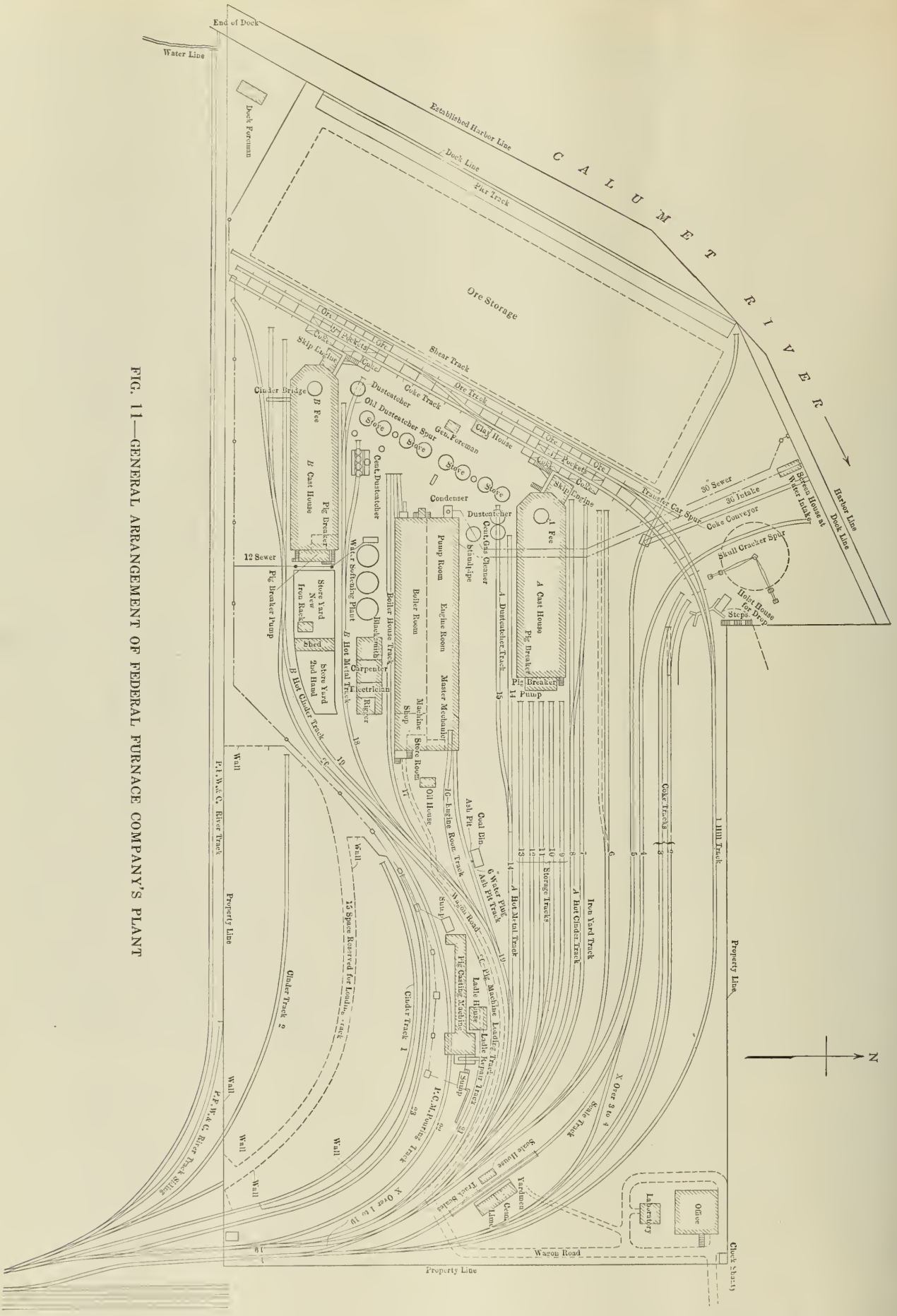


FIG. 11—GENERAL ARRANGEMENT OF FEDERAL FURNACE COMPANY'S PLANT

pile per furnace as great as is necessary, and this length is obviously the minimum distance between furnaces, for those conditions.

There are many other considerations affecting the spacing of the furnaces, however, especially in those cases where considerations of the size of the stock pile

do not control them. It is very undesirable to have the furnaces crowded together as it is more difficult to work around them under those conditions, more danger is likely to be done to one furnace by an accident at another, and questions of accessibility of various kinds arise which it is practically impossible to provide for in detail in advance, and which can only be met satisfactorily by having a certain amount of room around each furnace.

On the other hand, it is undesirable to have them spaced too far apart on account of the initial expense of land, tracks, etc., and such spacing not infrequently defeats its own ends by offering a temptation to put something into the unoccupied space, another furnace or some other part of the plant. This has happened on more than one occasion. The supervision of furnaces is also more difficult when they are scattered over too wide a territory. One blower can frequently blow two furnaces if they are spaced close together, but would not be close enough to the work to manage two located very far apart. When the stoves for each of a pair of furnaces are arranged in a continuous row as shown in Fig. 11 this in itself controls the minimum distance of the furnaces apart, as it virtually does at that plant.

Furnaces are very generally arranged in pairs, rights and lefts, as shown in Fig. 11, and more clearly shown in Fig. 13, which illustrates the arrangement of a pair of furnaces with their stoves, gas mains, etc., in some detail. On the other hand, at one of the best built and most successful plants the plan was adopted of having the furnaces all built the same "hand," that is to say, looking at the plant from the front, the stoves are all on the left hand side of their respective furnaces.

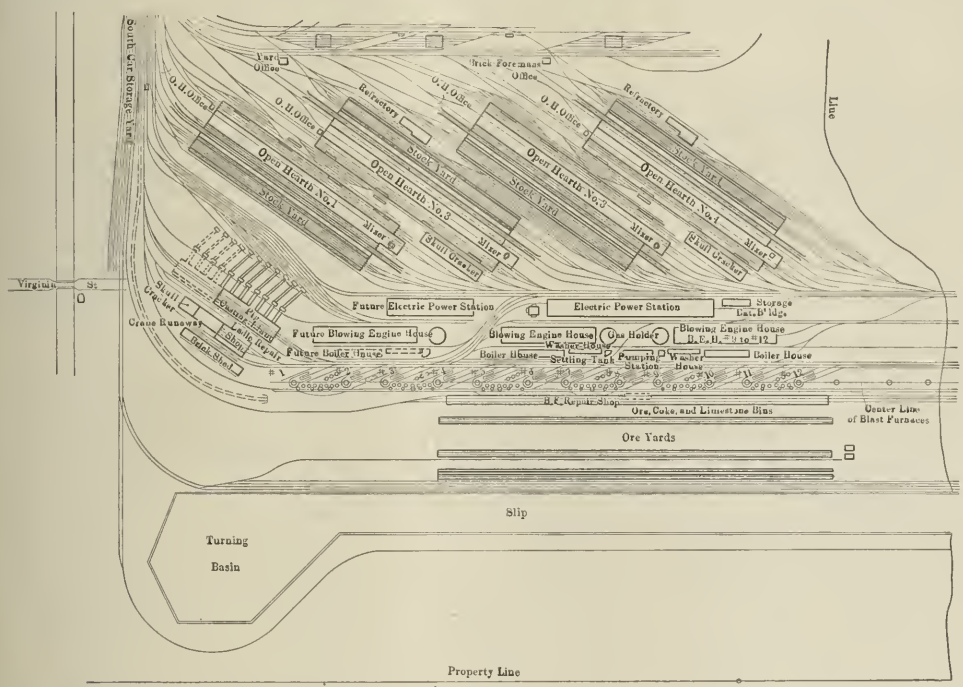


FIG. 12—GENERAL GROUND PLAN AND TRACK LAYOUT FOR THE PLANT OF THE INDIANA STEEL COMPANY AT GARY, IND.

One of the advantages of the pair arrangement is that it makes the distance between furnaces alternately very short and quite long. The close grouping of one pair of furnaces is an advantage since that is about the limit of what a single blower can supervise satisfactorily, and having these two close together makes it possible for him to keep in much closer touch with their operation. The fact that the next pair is several hundred feet away is of no importance to him whatever.

The Arrangement of the Stoves and Hot Blast Main

This is a subject deserving the most careful consideration. Stoves in modern practice are universally arranged in one straight row, where considerations of room permit, but this exposes the maximum amount of surface to radiation, takes up the most room, and requires the longest hot blast main.

About thirty years ago the late Samuel Thomas built the Pioneer Blast Furnaces now owned by the Republic Iron and Steel Company in Birmingham, with the four stoves at the four corners of a square, with the hot blast main running between them. This takes up much less room than the linear arrangement and shortens the length of the hot blast main by the diameter plus clearance of two stoves, and where room is a matter of importance this plan is worthy of serious consideration.

The location of the stoves in relation to the furnace is a matter of much importance from another point of view. The hot blast main becomes heated to quite a high temperature in spite of a heavy lining of fire brick, and as a result expands in ordinary cases from one to three inches. No expansion joint has as yet been designed that is satisfactory for this service on account of the high temperature to which it is necessarily more or less exposed, and in consequence one end or the other of the hot blast main must move. Owing to the construction of the hot blast valve seats shown in an earlier article these act as expansion joints to the extent of about half an inch or an inch. That is, the main can slide on the flat surface of the joint to this extent without breaking anything. The bustle pipe is suspended from the furnace itself on swinging hanger bolts, and these are free to move more or less, but movements of the bustle pipe in relation to the center of the furnace are extremely undesirable because if it was put up truly concentric with the furnace originally every change must move it from the center, which means that the distances from the base of the tuyeres to the bottom of the penstocks is not constant, as it should be, but longer on one side of the furnace than on the other. This necessitates having special blow pipes for some or all of the tuyeres and greatly increases the spares necessary to be kept on hand, and, what is even more important, increases very greatly the difficulty of changing tuyeres or the like on account of the difficulty of securing the right length of blow pipe.

For these reasons the design of the hot blast main, particularly in relation to expansion, should be very carefully considered before a final plan is adopted.

The Elevation of the Furnace

Furnaces in the early days were set practically flat on the ground and their operating level was the general ground level, it being possible to walk about them without the intervention of stairs of any kind. But the tendency has steadily been to raise the furnace proper

higher and higher above the furnace ground, primarily to permit placing ladle cars under the spouts delivering the iron and cinder from the cast house. Many low built furnaces were equipped for handling cinder in hot pots by digging deep pits for the ladle tracks and running down into these on a sharp grade. This is a way out of the difficulties which arise by not having sufficient height but it is an exceedingly poor one because it increases enormously the difficulty of pulling the cars out of the pit and of handling them in it. Moreover if a "mess" occurs, as it occasionally does in spite of the best management, the cinder and often the iron flow into the pit, or fill up the ladles, and then overflow them running down into the pit itself and making in some cases a pool two or three feet deep of molten iron and cinder at the bottom of a deep pit with masonry walls. The task of removing this, which is absolutely necessary before the furnace can be put back into operation, is bad enough to contemplate but much worse to experience, while the expense of the delay and repairs to tracks are very heavy. Even where the pig iron is handled cold, by hand, it is extremely desirable to have the cast house set well above the level of the iron shipping tracks since frequently transfer trucks are used in tak-

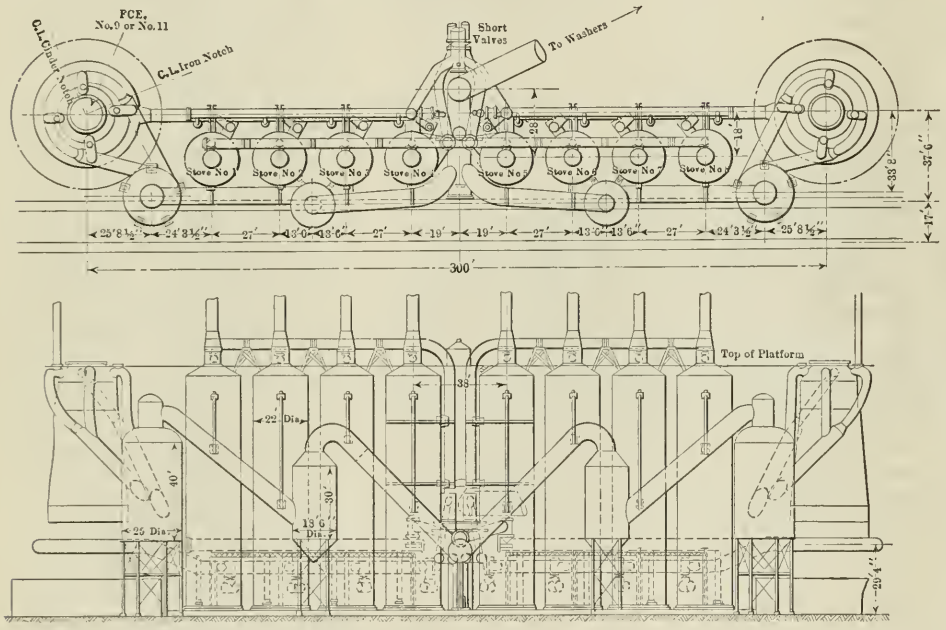


FIG. 13—GENERAL GROUND PLAN AND ELEVATION OF A PAIR OF FURNACES WITH THEIR STOVES AND DUSTCATCHER. INDIANA STEEL COMPANY, GARY, IND.

ing the iron from the cast house to the iron scales or the storage yard, or to the broad gage cars for final shipment. It is of course important to be able to drop the iron down to these transfer cars and also to drop it again to the standard gage cars. All of these considerations have demanded that furnaces be set higher and higher with the result that the hearth level at modern furnace plants is from 15 to 20 feet above the ground level.

The tracks serving the cast house and the cinder runners instead of being of the "dead end" variety as they must be if they are in pits, are, if possible, always made through tracks on the ground level, so that if there be an obstruction in one direction the liquid iron and cinder may be hauled away in the other.

It is probably advisable to go even a step further than this and to have the level of these tracks where the ladles stand on them raised a little above the level of the surrounding territory so that in case of a breakout or other accident the runaway iron and cinder instead of forming a pool on top of the tracks to their complete destruction may run down hill off of them.

The Arrangement of the Boilers and Engines

The blast can be carried for very considerable distances from the blowing engines without much loss of pressure and with but little expense. It is therefore possible to locate the blowing engine house at a considerable distance from the furnaces, but of course it is very undesirable to carry the steam any further than is absolutely required. This means that the boiler house must be located close to the engine house, and as the gas from the furnace must be brought to the boiler house the location of the latter is deserving of considerable study.

At small plants attempts have been made to set boilers and stoves close together so that one man could attend both sets of burners, and this is on many accounts an excellent idea, but cannot generally be followed at larger plants, and therefore a location is chosen for the boiler house which will give the shortest and most convenient gas main to reach it and at the same time give the best steam connections to the engine house. It might almost be said to be standard practice to put the engine house and boiler house parallel and close to one another, although very many plants have departed from this practice for one reason or another.

Where room is an important consideration these two buildings can be placed in spaces relatively difficult of access without much detriment because very little material has to be hauled to or from them on railways, but, of course, provision must always be made to bring in an ample coal supply for the boilers even though it be useless 95 per cent of the time.

It is almost indispensable that the engine house should be served with a track to handle the heavy parts of blowing machinery during erection and subsequently during repairs, but these tracks being very little used need not have the location and alignment required for tracks carrying a continuous and heavy traffic.

The number of furnaces served by a single blowing plant must be decided by the general arrangement of the plant along the lines laid down above. The expense of carrying the blast is, as there stated, not very heavy. At the same time if it were attempted to supply blast for a large plant of eight or ten furnaces from a single blowing engine house the quantity of piping involved would become very large, and the room which these pipes would take up running, in many cases, close to one furnace in order to reach others would be a very serious matter. For this reason it is possible that four furnaces is about the limit of the number that can be advantageously blown from a single engine house. Moreover, it is to be noted that when the number of engines in the plant has reached the limit of what one given crew can supervise adequately another crew then becomes necessary, or a large portion of one, and it makes little difference in the operating cost whether these be in one house or in

two, while it makes an enormous difference both in cost and in room required if blast pipes for more than four furnaces have to be distributed from a single blower house.

The electrical, compressed air and dry blast plants are almost always located, as they should be, in or adjacent to the blowing engine house so as to be under the charge of the blowing engine operators, and served by the cranes installed over the blowing machinery. The feed pumps for the boilers were formerly in the same building but are now very generally placed in the boiler-house proper and put under the charge of the boiler house attendant. The pumping plant must be located primarily with relation to the water supply, and while it is exceedingly desirable that this also should be in the main power house it is not always possible to arrange it in that location without sacrificing even more important considerations. At the same time the cost of attendance of isolated plants of relatively small power is very high as compared to that in a single large power house, and for this reason the pumping plant should be either in the main power house or as close to it as practicable.

Arrangements for the Disposal of the Iron

These necessarily vary according to the purpose of the plant. If it be a component part of a steel works then the prime consideration is safe and convenient methods of hauling the ladle cars to and from the steel works. If on the other hand the furnaces constitute a merchant plant all the iron is required to be cast either in beds or a pig machine. In the latter case the location of the pig machine is a matter of some moment as is also the location of its service tracks. In an earlier article were given a description and illustrations of a pig machine plant with an excellent arrangement of "ladder" tracks. Such an installation can within reason be located wherever consideration of tracks and space require.

The Disposal of the Slag

The prime consideration in this is that the runners shall be short since even the hottest and best-running cinder builds in the bottom of the trough and has to be cleaned out and disposed of before the next flush. The labor required for this increases almost as the square of the length of the trough and it is therefore very important to keep the latter as short as possible whether it is to discharge into a hot pot or into a granulating pit.

The location of the slag dump for the final disposal of the slag may be any distance up to one or two miles or even twice as much, but of course it is desirable to keep this distance as small as possible in order to diminish the time of the ladle cars on the road and so enable the smallest number of them to perform the necessary service.

Panama Canal Commission Award.—The contract for furnishing material under circular No. 891 for complete pumping plant for Dry Dock No. 1, Balboa Terminals, Balboa, Canal Zone, Isthmus of Panama, was awarded by the Panama Commission to Henry R. Worthington, N. Y. The contract involves design, fabrication and delivery on the Isthmus of the structural, mechanical, electrical and hydraulic parts required for this installation. The pumping plant comprises four 1000-hp. main pumps, two 200-hp. drainage pumps and one bilge pump. The contract further includes all of the hand and power operated gate valves as well as the automatic check valves. For operating the gate and sluice valves by power a hydraulic pressure system is provided consisting of a weighted accumulator and the necessary pressure pumps in duplicate. Delivery is guaranteed within 210 days.

Faraday Society Meeting

The seventy-fifth ordinary meeting of the Faraday Society was held on May 11, 1915, at the Institution of Electrical Engineers in London. The president, Sir Robert Hadfield, was in the chair.

Prof. ALFRED W. PORTER read a paper "On Von Babo's Law and Kirchhoff's Equation for the Latent Heat of Dilution."

The following are the chief points in the paper:

1. Accurate formulas are found for the heats of dilution (both reversible and irreversible) for a solution of any concentration at any hydrostatic pressure.

2. A sufficiently accurate formula is obtained connecting the heat of dilution with vapor pressures. Von Babo's law is discussed in this connection.

3. It is shown that, at any rate for sugar solutions

$$\log \frac{\pi}{\pi_o} = \frac{n}{N - an} \text{ approximately,}$$

where a is the hydration factor of the solute.

4. It is emphasized that $N - an$ cannot be interpreted as the number of effective molecules of solvent in the solution on account of the association of the solvent molecules with one another. For example, in the case of water the association is almost certainly between 2 and 3. Hence the actual number of solvent molecules *in the solution* which are unattached to solute is between $\frac{N}{2} - an$ and $\frac{N}{3} - an$; because N is the number of molecules of solvent reckoned as in the vapor state, and steam is not associated.

Mr. D. ORSON WOOD read a paper on "The Vapor Pressure of Concentrated Sugar Solutions."

The vapor pressure of solutions containing approximately 50, 60 and 70 grams of cane sugar per 100 grams of solution have been determined by a static method for the temperature range 60 deg. to 90 deg. C. The results show that the lowering of the vapor pressure of the solution relative to that of water (Babo's constant) decreases slowly with temperature, and the variation indicates that heat should be evolved when the solutions are diluted with water, thus agreeing with the previous work on the latent heat of dilution.

The value of Callendar's hydration factor a is calculated for each solution. It varies continually with temperature from 3.5 to 4.5; but the mean in each case is very nearly 4, not 5, the value given by Callendar for less concentrated sugar solutions.

The osmotic pressure is deduced from the vapor pressures by means of Porter's equation. For the strongest solution it is of the order of 320 atmospheres. It has a tendency to decrease with rise of temperature. The theoretical aspects of all these results are considered at length.

A paper by Mr. F. J. HARLOW and Mr. R. S. WILLOWS on "A Simple Method of Deriving the Gibbs Adsorption Formula" was read by Mr. Harlow.

The usual method of deriving the Gibbs adsorption formula involves the use of chemical potential. As students find a difficulty in understanding this, a simple method of obtaining the formula is given which involves only elementary thermodynamics.

Mr. F. H. CAMPBELL communicated a paper entitled "The Vapor Pressures and Specific Volumes of Binary Mixtures of Volatile with Non-volatile Liquids."

By the use of a new method, the effect of varying quantities of a liquid of negligible volatility upon the vapor pressure of volatile liquids dissolved in them has been determined.

It has been shown that the results receive adequate qualitative explanation, on the assumption that the form of vapor pressure curves is determined by molecular

changes accompanying the process of solution. Thus the solution may consist of a smaller number of particles than did the liquids constituting it before admixture, as the result of solvate formation; the number may be greater, owing to dissociation of an associated liquid. Probably the commonest case is that in which both solvate formation and dissociation occur together.

Attempts to apply Dolazalek's theory quantitatively were not successful, even in the simplest cases. It must be concluded that it requires amplification.

An explanation of the apparently abnormal behavior of certain mixtures is put forward.

The specific volumes of a number of mixtures of pairs of liquid have been determined.

Mr. R. H. Callow communicated a paper on "Reaction Velocity in Viscous Media."

The reaction considered was the hydrolysis of methyl acetate in gelatine-water mixtures by NaOH and HCl. Conductivity experiments on the alkaline hydrolysis failed to give satisfactory results owing to the hydrolysis of the Na salt of gelatine. The acid hydrolysis gave a series of velocity constants which showed a diminution as the gelatine concentration increased. The change in the velocity constant was small compared with the change in the viscosity, *e. g.* the velocity constant for the reaction proceeding in a set jelly was only about 10 per cent less than that in the case where no gelatine was present. The curves showing the relation between the velocity constant and the viscosity and fluidity of the mixtures do not appear to obey any simple relation. The fall in the velocity constant is supposed to be due partly to the neutralization of the HCl by the gelatine, and partly to the viscosity. The author suggests that the effect of the viscosity is given either by a reciprocal relation such as $\eta(K - c) = \text{const.}$, where c is a constant, or by an exponential function.

Mr. K. C. Browning and Mr. C. T. Symons sent in a description of "A Convenient Thermostat for Accurate Specific Gravity Determinations and a Gas Pressure Regulator."

The authors, having had occasion to make a number of accurate specific gravity determinations, devised a thermostat the temperature of which can be kept constant to considerably less than 1/100 deg. C., which has advantages over others they are aware of.

The advantages of this regulator are:

1. It does not leak either at the valve or at the flexible top. If a gas pressure of 30 in. water be applied at the inlet, a water gauge at the exit will not alter its level perceptibly when the pressure at the inlet is maintained for half an hour.

2. It is portable and takes up little room.

3. It can be rapidly set for any desired reduction of pressure.

4. It does not require careful leveling and is very strong.

Mr. E. J. Hartung communicated a paper on "A New Method for Determining the Specific Heats of Liquids."

In the course of a research on certain thermal properties of binary liquid mixtures it was found necessary to measure the specific heats of a large number of liquids. It was therefore very desirable to have a simple, rapid and reasonably accurate method of measurement. The paper contains an account of a method which has been found very suitable for the purpose named. It has the added advantage of requiring a relatively small quantity (60 c.c.) of the particular liquid for a determination. The method retains the simplicity of the old mixture method for measuring specific heats while greatly diminishing its serious errors.

The initial idea, from which the method was worked out, was supplied by Prof. Orme Masson, who suggested that the liquid in question be cooled by the application of a known weight of dry ice sealed up with a roll of silver gauze in a thin glass bulb. This suggestion was acted upon, and, after suitable apparatus had been constructed, good and consistent results were obtained. The method in brief consists in freezing the bulb containing the water in a suitable apparatus and then introducing the bulb into the liquid in the calorimeter and noting the fall in temperature.

Mr. J. S. Anderson contributed a paper on "An Electromagnetic Vacuum Balance."

The balance was designed to allow weighings being carried out *in vacuo*. The principle involved is that of the well-known Kelvin balance for "weighing" electrical currents. One of the scale-pans of an ordinary balance is replaced by a circular coil of wire which is movable between two larger fixed coils of wire, the three coils having a common vertical axis. The coils are so connected that, when a current of electricity is passed through them in series, the movable coil is attracted by the lower, and repelled by the upper, fixed coil. These attractive and repulsive forces, which may be increased or decreased by varying the electrical current, are made use of to counterbalance the action of gravity on the substance to be weighed in the scale-pan hanging from the other end of the balance-beam. Should the weight of the substance vary from time to time, the variations in weight can be determined by altering the current through the coils until equality of the forces acting on the two ends of the balance-beam is obtained. The balance must first, of course, be calibrated.

The base of the balance is fixed to a glass plate, over which a bell-jar is placed, thus allowing of the apparatus being evacuated. Two terminals, which serve for leading in the current for the coils, pass through the glass plate. The arrestment is controlled by an electromagnetic device operated from outside the balance. Attached to a lever at the back of the balance are two iron rods which can move freely in a vertical direction inside two solenoids. When an electrical current is passed through one solenoid the balance beam is released; when passed through the other solenoid, the beam is fixed. As soon as the beam is either released or fixed, the current may be switched off without altering the position of the beam.

A difference in weight of .35 to .7 milligram could easily be detected when use was made of an amperemeter which was not very sensitive. The balance is specially suited for measuring changes in the weights of substances *in vacuo*. Measurements were made of the velocity of absorption of water vapor by silicic acid gels.

Mr. E. B. R. Prideaux sent in a "Note on the Neutralization Curve of Boric Acid."

The hydrion concentrations of boric acid at various degrees of neutralization may be calculated with one dissociation constant. If that of Walker $K = 1.7 \times 10^{-9}$ is used, the calculated acidities over the greater part of the curve are too high as compared with the experimental values of Sorensen. A modified dissociation constant $K = 4.5 \times 10^{-10}$ derived from these values gives a good agreement, except that the acidity is too low at the acid end.

These differences are accounted for by the formation of complexes in solution.

Mr. Norman Murray Bell contributed a paper "On the Anodic Solution of Lead."

This paper is due to an attempt made to collect further evidence bearing on the production of monovalent lead ions (Pb.), the existence of which in aqueous solution has been inferred by Denham (*F.C.S.*, 93, 424, 833).

The results of the preliminary investigation of the

electric solution of an anode of pure lead in six different electrolytes, viz. lead acetate, potassium hydrogen tartrate, hydrofluorsilicic acid, sodium acetate, potassium bromide, and sodium thiosulphate, are here recorded. Of these the sodium acetate and the sodium thiosulphate yield apparently positive evidence. The author hopes to be able soon to supply a more detailed study of these two solutions.

Mr. F. C. THOMPSON communicated a paper on "The Elastic Strength of Metals."

In a normal pure metal the inter-crystalline boundaries are by far the strongest part of the whole. This rather unexpected fact has recently been explained by assuming that a hard vitreous modification of the metal exists between the crystal grains, the strength of which "cement" is sufficiently great to stiffen up the whole mass. This explanation, however, necessitates the assumption of a tensile strength for the cement of an almost impossible order.

On the assumption that surface tension effects are to be expected in the "glassy" films, an expression for the elastic limit of a pure metal is derived.

If E is the E.L. in dynes per sq. cm.,
n is the number of crystals per cm.,
T is the surface tension of the films, and
d is their thickness,

$$E = 1.5n\frac{T}{d} \qquad (1)$$

The equation agrees well with recent work on the yield-point in metals and on their mechanical properties at high temperatures.

Bars of pure lead, tin, zinc, antimony, silver, copper, iron and nickel were used to test the relationship, the iron being used in five different conditions.

Although this equation governs the elastic limits of metals, the maximum stress and Brinell hardness are dependent on other terms, chiefly the "intrinsic pressure," with the result that alterations may be made in the elastic limit of a material without appreciable effect on its hardness.

The electrical resistance of a normal metal ρ is shown by measurement of the samples of treated iron to be the sum of the resistance of the crystalline material ρ_1 and an added resistance due to the crystalline junctions, so that if n is the number of the latter per centimeter and R their resistance,

$$\rho = \rho_1 + nR \qquad (2)$$

Thus from (1) and (2)

$$d = \frac{1.5T}{E} \cdot \frac{\rho - \rho_1}{R} \qquad (3)$$

which allows d, the thickness of the film of undercooled metal between the crystals, to be calculated.

Results are obtained for a pure iron, and discussed in their bearing on the theories of the origin of the films.

Mr. LESLIE AITCHISON sent in a paper entitled "Experiments on the Influence of Composition upon the Corrosion of Steel."

The work embodied in this paper has been performed upon a series of some sixty steels, comprising (1) plain carbon steels, (2) steels containing a constant proportion of carbon and varying proportions of tungsten, chromium, cobalt or vanadium, (3) steels with constant proportions of tungsten, chromium, vanadium, manganese or nickel, and (4) some steels containing copper. The attacks recorded are those of (1) 3 per cent sodium chloride, (2) 10 per cent sulphuric acid, and (3) 1 per cent sulphuric acid. The work shows that in the case of the pure carbon steels an increase of the carbon produced at first a fall of the corrosion and then a rise to a well-marked maximum of 0.9 per cent of carbon. The addition of varying proportions of tungsten to a series of steels containing about 0.7 per cent of carbon has produced a definite increase of the corrosion throughout. Varying percentages of cobalt added to a similar series have produced an increase of the corrosion with the presence of smaller quantities of cobalt, and in all cases a gradual fall of corrosion with a rise of cobalt. In the two acid solutions the higher proportions have produced a corrodibility less than that for the corresponding pure carbon steel. The presence of vanadium in varying proportions has resulted in a definite increase of the corrodibility. The addition of chromium produces an increase of the corrosion up to 5 per cent, then a remarkable fall to a material containing 19 per cent of chromium, which is quite non-corrodible in brine, and almost so in 1 per cent sulphuric acid, but which is highly corrodible in 10 per cent acid.

In the third series the percentages of the third elements present are fairly low, and the addition in all five cases has produced an increased corrosion in brine. In the 1 per cent acid, tungsten and nickel have (in general) produced a decrease, while vanadium and manganese show a tendency to produce an increase of the corrosion. In the 10 per cent acid, tungsten and nickel generally produce a decrease, while chromium, manganese and vanadium show a distinct increase. The steels containing copper show an increased corrosion in brine and 1 per cent acid, but a decreased corrosion in 10 per cent acid, after the copper has risen above 1 per cent.

In general it is suggested fairly strongly that anything tending to the production of finer pearlite in steels, but which does not produce a mixture of carbide and solid solution (as distinct from a eutectic), causes an increase in the corrosion of the material. The relation of the presence of carbides to the corrosion is also discussed. Further conclusions to be drawn from the work are postponed until other experiments on the question have been published, these being promised for the near future.

The discussion on this paper was postponed until the autumn, when a general discussion will be held on "The Corrosion of Metals—Ferrous and Non-ferrous."

Oxy-Hydrogen Electrolytic Cells for Japan.—The Tokio-Electric Co. has ordered a large installation of I. O. C. cells for the electrolytic production of oxygen and hydrogen gas from the International Oxygen Co., of New York.

Electric Steel Furnaces.—The Halcomb Steel Co., of Syracuse, N. Y., who installed the first electric steel furnace in America seven years ago, have contracted for a three-ton Snyder electric furnace, which will run basic, melting and refining cold material. It will have a 24-hour output of 24 tons of refined steel and will melt cold scraps and refine it on a basic bottom. Messrs. S. Fair & Son, Inc., of Saginaw, Mich., have contracted with the Snyder Electric Furnace Co. of Chicago, for the installation of a furnace with a 24-hour output of 8 tons of refined steel. It will receive cold charges and will be used for making high-grade vanadium steel castings.

Antimony.—Construction on the first antimony smelting plant on the Pacific Coast was begun at Harbor Industrial City, Cal., on April 8. It is reported that the capacity of the plant now under construction and which is to cost $75,000 will be 1000 tons per month. It is to be built with a view to future extension to much larger capacity. The smelter is being erected by the Merchants' Finance Company represented by M. Elasasser and Henry E. Simpson on part of a 6-acre tract purchased for the purpose.

Metallurgical and Chemical Engineering in Great Britain

(From Our London Correspondent)

Technical and Scientific Attaches

In Elizabethan days a cynical diplomat described an ambassador as a good man sent to lie abroad for the sake of his country. I cannot remember a good epigram concerning naval and military attaches, nor can I perpetrate an indifferent one as to the new class of diplomatic officials suggested in a short paper appearing in the Journal of the Institution of Electrical Engineers. This short monograph pays a high tribute to many German qualities unrecognized in the days before the war: "Much, very much more than is supposed, of German success in the past has been due to the possession of scientific and commercial imagination. Others, time and again, have done the pioneer work, have opened new fields of discovery, but it has been left to the imaginative Teuton to carry the discovery to its logical conclusion, to foresee its fields of application, and to build thereon great and remunerative industries. We shall be indeed a short-sighted race if, when military warfare gives place to the commercial warfare waged by manufacturing countries for foodstuffs and luxuries, we do not strain every nerve to apply systems to our methods. We must remember that the added burdens not only of direct taxation but of reduced numbers of foodgetters will render commercial success more vital to our welfare than in the past. Europe has had one example of an economic rehabilitation and industrial renaissance of a conquered nation following upon defeat and the payment of a big war indemnity. It is well within the bounds of feasibility that German industrialism may make a recovery not quite so rapid, but sufficiently rapid to justify forethought at this stage. At the time of writing, her factories and equipment are uninjured. Only raw materials and markets are needed for industrial production to be resumed. The raw material can be produced or obtained; there will be every incentive to regain the latter. Just as the important and in some respects almost dominating position which Germany held in the neutral markets of the world before the war was in part due to the thorough and systematic methods of her commercial engineering departments, so her innate gains of organization and co-ordination, her capability of concentration of purpose, and her logical industrial imagination, will guide and steady her progress toward a recovery of her previous position. To this she will be relentlessly spurred by the grimmest of necessities, that of food earning."

The remedy or weapon advocated by the author of the monograph is that of a new type of attaché at our legations and embassies. "Unless written by specialists, neither the reports of commercial attachés and trade commissioners nor the consular reports can be reasonably expected to give details, say, of the successful types of competing foreign manufactures, the reason of lower price, the reasons apart from price why British types are not successful, and the local conditions which may render British articles unsuitable.

"The professional status of a technical commissioner, say, in engineering, should be at least the equivalent of full membership of one or more of the institutions most closely concerned in his work, viz., the respective institutions of mechanical engineers and of electrical engineers. Those concerned with mining machinery or metallurgical matters should belong among other bodies to the Institution of Mining and Metallurgy. The chemist, too, should possess equivalent qualifications. Were it once decided to appoint technical commissioners, the councils of the various institutions could submit names to the Secretary of State, who would make a selection therefrom in the usual manner. Before proceeding to take up his post, the newly appointed technical commissioner should have ample opportunity of conference with representatives of the industries concerned with his sphere of work, both as regards their selling and their technical departments, and methods of manufacture. At stated intervals he should return to England to confer with those concerned in his work."

The author has, however, omitted to say that certain reports issued by your Bureau of Standards in Washington would prove useful models, and are convincing examples of what can be done. Also, too, but not so well known, are the published Japanese reports. The unpublished Japanese reports, moreover, would probably surprise many people, not only in Europe but on your side also.

Government Aid for Scientific Research

The Rt. Hon. J. A. Pease, who until the reconstruction of the Cabinet was President of the Board of Education, has made a very important announcement in the House of Commons. In the course of his annual statement he observed that the war had shown up the fact that Great Britain was far too much dependent on the foreigner for many processes and for much material. It had made us realize that if we were to maintain our manufacturing position in the world we must endeavor to promote a better system for the encouragement of scientific research, especially in the universities. He stated that he could give case after case where, by research and by a little expenditure in connection with the training of scientific and able men, we would be able as a country to succeed just as Germany had succeeded. His fear was that after the war we should have to contend with a fiercer competition than that which we had had to contend with in recent years. The government agreed with him that something ought to be done at once, that we must make more use of the workers who exist in our country and prepare for an increased supply of them, that we must bring our universities and technical schools into closer association with industries and bring our leaders of industry into closer association with skilled workers. He proposed to proceed at once to the appointment of an advisory council in industrial research. He wanted a committee of experts who themselves would be able to consult with other expert committees working in different directions. They in turn must be associated with leaders of industry. The department would work in close co-operation with the Board of Trade. He hoped the Advisory Council would be at work within the next few weeks. He hoped to place on the supplementary estimates a vote of between £25,000 and £30,000 as a beginning. The schemes must be dependent on state help for years to come, and this state help must steadily progress.

The Iron and Steel Institute

THE SECOND DAY'S MEETING

The second day's meeting was much quieter than the first. A resolution drafted by the Council removing the names of all alien enemies from the list of members was considered and adopted. After this the Carnegie Medal, which had been awarded to Mr. E. Nusbaumer of Paris for his researches on "Rotary Bend Tests," was handed to Mr. H. Le Chatelier, as Mr. Nusbaumer was serving with an artillery regiment.

The first paper discussed was that by Dr. A. McWilliam and Mr. E. J. Barnes on the "Brinell Hardness and Tenacity Factors of a Series of Heat-Treated Special Steels."

Dr. C. A. Edwards, who opened the discussion, said that in certain experiments which he had carried out with chrome steels he had found that when heat-treating them in various ways he obtained different variations in the Brinell hardness; this he illustrated by a number of curves on the blackboard. He had concluded from the tests he illustrated that chrome steel was a self-hardening steel. When tungsten was also present the effect was not due to the tungsten, but was due to the chromium. He (the speaker) had taken curves of a 6 per cent chrome steel, and had found that in cooling down great variation occurred in the occurrence of the critical points, and his experiments pointed out that by carrying out cooling at different rates in a laboratory it was possible to control any property of the steel.

Mr. H. Le Chatelier, who followed, said the experiments carried out by Messrs McWilliam and Barnes confirmed the absence of proportionality between the Brinell hardness number and the yield point. For the passing of certain material in the case of which the yield point was of the greatest importance, the use alone of the Brinell test would not afford a sufficiently accurate guide. On the other hand, the Brinell test could be resorted to, and serve as a guide when other conditions are extant for determining the metal; when, for example, the chemical composition or thermal treatment was known. The constancy in these conditions, coupled with the fixity in the hardness number, sufficed to show that the characteristics of metals which were being compared together remain constant, the yield point, therefore, remaining also constant.

Dr. Stead found the paper most interesting, in that it pointed out the value of the Brinell testing machine. This machine was now in almost constant use, and it should be met with in every works, since in one minute it was able to give a good indication of the properties of the steel.

Dr. Rosenhain said it would be wrong for the Brinell test to be resorted to for investigating new material, but it was a useful method for a number of purposes, such as routine tests carried out when comparing series of similar pieces similarly treated. He indorsed Mr. Le Chatelier's remarks.

Dr. J. E. Stead then read an abstract of his paper on "Iron, Carbon and Phosphorus." Much of the discussion was devoted to methods of detecting phosphorus —the beautiful photo-micrographs in color which accompanied the paper were greatly admired, and favorite etching media warmly praised or sharply criticized according to the predilections of the speakers. For instance, Dr. W. H. Hatfield was not really satisfied with either Dr. Stead's or Dr. Rosenhain's reagents. Mr. H. Le Chatelier said that a very simple means for characterizing phosphide of iron was to have recourse to caustic soda and electric current. The phosphide of iron was attacked and the cementite remained intact. He added that electrolytic methods could, he thought, be used more frequently than they were at the present time; they made it easily possible to regulate the action of the reagent.

Dr. Rosenhain said that the reagents were new in the sense that they had been worked out a little more fully than formerly. Osmond used copper solutions for etchings, but he (the speaker) believed Osmond removed the copper from the surface. There were two kinds of actions, a dissolving one and a pure etching one, with at the same time a deposition of copper. One or the other might preponderate. If the etching action preponderated the effect would be similar to that with picric acid. Ghost lines were so common in all commercial steel that it was ridiculous to say that the mere existence of bands containing more or less phosphorus necessarily rendered the steel bad. But when the bands were excessive in number or in width and intensity, it was necessary to beware of them. There was a concentration of phosphorus in the bands. There occurred also alternate layers of two materials which differed in their critical temperatures and in their mechanical properties, both hot and cold. They were being rolled or forged together, and they were unequally expanded in the process. Their internal behavior was different, with the result that internal stress was produced when the metal cooled. Where large plates had cracked spontaneously, the cracking was associated with a large amount of banding and with a large difference in the phosphorus content between successive layers. There was also the effect of the bands upon the critical points of the steel. He (the speaker) thought Dr. Stead had got over the difficulty with his reagent. To judge properly of the new copper solutions extremely low magnifications had to be used, 2, 3 or 4 diameters at most. He (the speaker) thought Dr. Stead was right when he said that the whole question of the rate of deposition of copper was the ease of sollubility of the ferrite, and consequently the question of the purity of the ferrite. Carbon dendrons were not obtained when the metal was etched with picric acid, because the carbon diffused so rapidly. Silicon diffused more rapidly than phosphorus. Phosphorus, in fact, was one of the most slow diffusing components, if not the slowest.

Other speakers included Mr. E. H. Saniter, Mr. R. G. Scott, Dr. McWilliam and Dr. Edwards. Dr. Stead in his reply agreed with what Dr. Hatfield had said, as his own experience was practically identical. But the reagents were not intended to apply to pig iron, to which Dr. Hatfield had applied them. With pig iron Dr. Stead had also found they not only showed the phosphorus areas, but also silicon concentrations, which had never been shown in pig iron by any other reagent. Up to 5 per cent silicon there occurred a large area which remained white. The graphite had decomposed into pure iron and graphite, while the silicon in the primary crystalite form had not had time to diffuse out. Dr. Hatfield's magnification was too great. Mr. Le Chatelier's method was a good one for detecting free phosphorus, but it did not apply to phosphide in solid solution. He agreed with Dr. Rosenhain on all points. Other things besides phosphorus interfered, and it was necessary to be careful in the use of reagents.

The last paper read and discussed was that by Mr. Kotaro Honda of Tohoku University, Japan, and dealt with "The Nature of the A_2 Transformation in Iron." The speakers were Dr. Stead, Mr. H. Le Chatelier and Dr. Rosenhain.

Market Prices

JUNE, 1915

Tin opened at £162, fell to £160 (3d), and then rose steadily to £167 (9th). After a slight drop to £166.10 (10th) it rose sharply to £175 (14th), then fell to £168.10 (17th), recovered to £171 (19th), again dropped to £168.10 (25th), after which it improved considerably, closing at £172.10.

Haematite has remained steady at 95/- throughout the month.

Scotch Pig opened at 71/6, and remained steady till the 8th, it then rose slowly to 74/- (15th), declined to 72/- (20th), recovered to 72/6 (22d), and after slowly falling to 72/- (29th) it rose slightly, closing at 72/6.

Cleveland opened at 65/6 and remained steady till the 8th, it then improved to 67/6 (15th), declined to 66/- (20th), recovered to 67/- (22d), and after slowly falling to 66/- (29th) it rose slightly and closed at 67/-.

English Lead opened at £21.10 and rose steadily to £28.10 (15th), it then dropped rapidly to £26.10 (16th), and after a slight improvement to £27 (18th) declined to £24.10 (24th). It then rose decidedly, closing at £27.

Copper opened at £79.10, improving to £83.5 (6th), and after a slight fall to £83.15 (8th) continued to rise to £86.10 (14th). It then fell sharply to £82 (18th), recovered to £83 (20th), but went lower to £81 (24th), and after improving to £82.10 (25th) it declined slightly, closing at £82.

	£	s.	d.
Aluminium, ton lots	105	0	0
Antimony, black sulphide powder, ton	70	0	0
Borax, ton	22	0	0
Copper sulphate, ton	29	0	0
Caustic soda, 70 per cent ton	10	2	6
Ebonite rod, lb.		3	0
Hydrochloric acid, cwt		4	6
India rubber, Para, fine, lb		2	7½
Mica, in original cases, medium	3 —to	5	0
Petroleum, water white, gal			9¾
Quicksilver, Spanish, bottle	16	10	0
Sal-ammoniac, cwt.	2	9	0
Shellac, cwt.	3	5	0
Platinum, oz. nominal	9	5	0

Recent Chemical and Metallurgical Patents

Iron and Steel

Combustion Apparatus for Carbon Analysis.—A form of apparatus for making carbon determinations has been patented by Mr. John S. Cox of Buffalo, N. Y. It is an improvement on the type in which a water-cooled stopper fits a crucible in which the combustion takes place. The idea is illustrated in Fig. 1, in which *A* represents the crucible and *B* the cover, the latter having the usual tubes *bb'* for ingress and egress of oxygen and other gases. The crucible has a flange *c* which fits into an annular depression *e'* in the annular cooling chamber *E*. The crucible cover *B* also has a flange *c'* corresponding with the flange on the crucible and between these two is placed a gasket of rubber, *D*. The cooling chamber has suitable inlet and outlet tubes *f* and *f'*, the latter not shown, for the circulation of cooling water. A screw *G* is provided to secure the cover firmly in place on the crucible and form a tight joint. Advantage is claimed over similar apparatus in which a cooling chamber is formed integrally with the crucible, because the cooling water forms incrustations in the chamber. An improvement is claimed also over apparatus with a water-cooled stopper, because the latter tends to condense atmospheric moisture on its surface that is likely to run into the crucible when the stopper is removed. (1,140,802, May 25, 1915.)

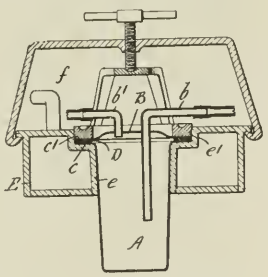


FIG. 1—COMBUSTION APPARATUS

Aluminium

Aluminium Nitride.—Some interesting developments in connection with aluminium nitride manufacture in the electric furnace, are brought out in patents recently issued to Mr. Paul Bunet of Whitney, N. C., and assigned by him to the Société Generale des Nitrures, of Paris, France, which company owns the Serpek patent. Special interest attaches to these developments in view of the fact that a large plant has been in course of construction at Whitney, N. C., for the manufacture of aluminium. Detailed information on the Serpek process may be found in Metallurgical and Chemical Engineering, Vol. XI, pages 137 and 139.

The raw materials are essentially the same in this new process as in the Serpek process, but the new process embodies a departure in the fact that the mixture of alumina or aluminous material and carbon is used itself as the heating resistor. The mixture advances in the furnaces in the same general way as in the Serpek process, but owing to the fact that carbon is used up in the reaction it is necessary to adopt some means of keeping the current normal. This is effected in two ways: either by increasing the thickness of the layer of mixture as it advances and becomes poorer in carbon; or by interposing electrodes into the mixture at intervals which can be adjusted according to the conductivity of the mixture between them.

Two types of electric furnace in which the above process may be carried out are also patented by Mr.

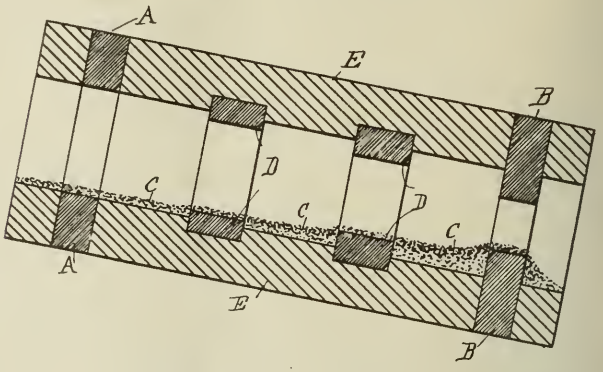


FIG. 2—ELECTRIC FURNACE FOR ALUMINIUM NITRIDE

Bunet. The first is a furnace in which the thickness of the layer of mixture increases with the advance, and the second effects the uniform passage of the current by having electrodes interposed in such a way that the distance between them can be regulated according to the conductivity of that part of the mixture. These two types may be combined. A drawing of an inclined revolving furnace of the first type is given in Fig. 2, in which *A* and *B* are annular conductors, the lower electrode *B* projecting into the furnace so as to form a diaphragm to retain the mixture *C* traveling through the furnace. *DD* are conductive rings which may be placed in the refractory lining *E*, thus allowing of a better passage of the current. These rings may be projecting on not. (1,145,747 and 1,145,748, July 6, 1915).

Aluminum Alloy.—An alloy consisting of aluminum, silver, copper, and cadmium, which is very useful for casting purposes, is patented by Mr. William A. McAdams of Bay Shore, New York. This alloy is not corroded by the action of the ordinary city water and has withstood pressures up to two hundred pounds per square inch without sweating. (1,146,185, July 13, 1915).

Zinc

Treating Zinc-Bearing Materials.—Improvements in electrical zinc smelting are the basis of a patent of Mr. Woolsey McA. Johnson of Hartford, Conn., and assigned to the Continuous Zinc Furnace Company of Hartford, Conn. A process is described for treating zinc-bearing slags, by reducing the zinc from the slags with iron, the zinc being subsequently volatilized and condensed. The slags treated are such as come from the lead blast furnace or from the reducton of ores containing zinc and copper. "Such slags are essentially silicate compositions in which iron and calcium predominate, carrying minor proportions of aluminium, manganese and magnesium, and containing some 8 per cent, more or less, of zinc oxide."

A cross section of the author's furnace is given in

Fig. 3, in which 1 represents the refractory structure, in a metal sheath 2. Interior chambers 3 and 4 are separated by partition 5, which is cooled by water pipes 6. A layer of molten iron on the hearth is indicated by 7 and 8,8 are the lower electrodes. Above the molten iron is a layer 9 of molten zinc-bearing slag, 10 being a runway for introducing same. The upper electrodes 11,11 depend into the slag. 12 is a flue for the volatilized zinc, 13 represents a tapping hole for slag, 14 a tap for matte, and 15 a lead tap communicating with a sump 16; 18,18 are hoppers for introducing coal or coke; 19 and 21,21 are tuyeres.

In operation of this particular type of furnace, the iron is run into the furnace in the molten state and in quantity sufficient to cover the hearth to a depth of a few inches. Fluid zinc-bearing slag is run in above the iron, and the temperature maintained at a point sufficient to effect the reduction of the zinc by the electric current.

This reduction occurs in accordance with the following reaction:

$$Zn\ O\ SiO_2 + Fe = Zn + FeO\ SiO_2.$$

The zinc vapor passes from the furnace by flue 12. The slag, denuded of most or all of its zinc, and proportionately enriched in iron, flows beneath the depending wall 5, into the furnace chamber 4, in which it is smelted in the presence of carbon. In this operation a certain portion of the iron is reduced to metal, and collects in the layer 7, serving to replenish same. The slag level may be maintained by tap 13 and lead carrying any gold and silver drawn out through tap 15. Instead of slag derived from lead blast furnaces or the like, the process may, of course, be operated with a properly compounded ore-charge from any source. In conjunction with a lead blast furnace the slag would be run into the electric furnace, thus conserving the heat, and "the lead blast furnace may be operated at high capacity and without strict regard for exact metallurgical conditions, the rich slags thereby formed being readily worked in accordance with the present process." (1,146,075, July 13, 1915.)

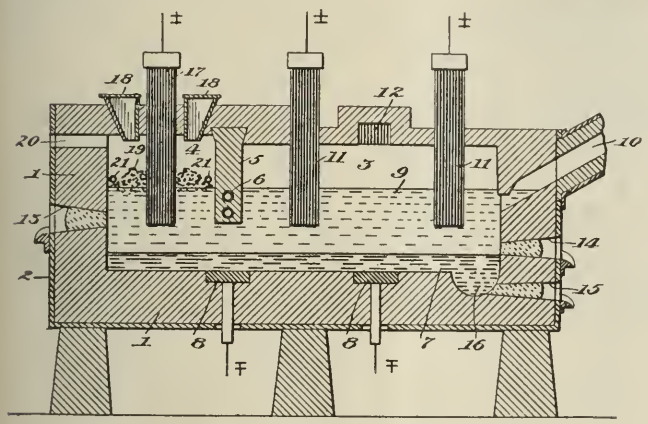


FIG. 3—ELECTRIC ZINC FURNACE

Roasting of Zinc Ores.—An improvement in roasting furnaces for zinc ores is patented by Mr. JOHN J. SIMMONDS of Iola, Kan., relating to that type of roaster in which two tiers of hearths are disposed side by side, and through which rabbles are drawn and transferred from the hearths in one tier to those in the other. The mechanism operating the rabbles is in connection with an engine or motor running continuously in one direction, and which does not have to be reversed in order to reciprocate the rabbles. The means for controlling the reversing mechanism, and for throwing the rabble-operating mechanism into and out of connection with the driving engine, are controlled from an operator's platform adjacent to the furnace. (1,133,068, March 23, 1915.)

Gold and Silver

Chlorination of Ores.—The production of electrolytic chlorine from salt for use in chlorinating the metals in gold, silver and copper ores, is the basis of a patent granted to Mr. JASPER A. MCCASKELL of Salt Lake City, Utah. An aqueous solution of the chlorides of the metals is subsequently electrolyzed in the cathode side of a diaphragmed cell, resulting in the regeneration of the original chloride solution and the deposition of the metals. The process and apparatus are illustrated in Fig. 4, in which *A* represents an agitating tank in which the ground ore pulp is treated with chlorine delivered from the tank *F* in which the gas has been stored under pressure. The chlorine gas itself is thus used as the agitating medium. If the ore contains silver, sodium chloride is added to the water used in crushing, being delivered from the tank *B*. After the first cycle the tank *B* will contain spent liquor from the anode compartment of the electrolytic cells. After the ore is chlorinated in tank *A* it is filter-pressed, and the liquor is delivered to the cathode compartment of the cells. The diaphragm is impervious and serves as a bi-polar electrode. It is formed of two sheets of asbestos or two pieces of porous earthenware between which is a thin film of mercury. The solution of metallic chlorides being under electrolysis, the metals collect at the cathode and the chlorine tends to accumulate at the diaphragm. In the anode compartment the sodium chloride is dissociated, the chlorine collecting at the anode and being used as already described, while the sodium collects at the diaphragm and amalgamates with the mercury. Ultimately reaction will occur between the sodium and chlorine at the diaphragm, and sodium chloride will be regenerated in the cathode compartment. The mechanical loss of chlorine would be made up by the addition of salt in the anode compartment. (1,137,874, May 4, 1915.)

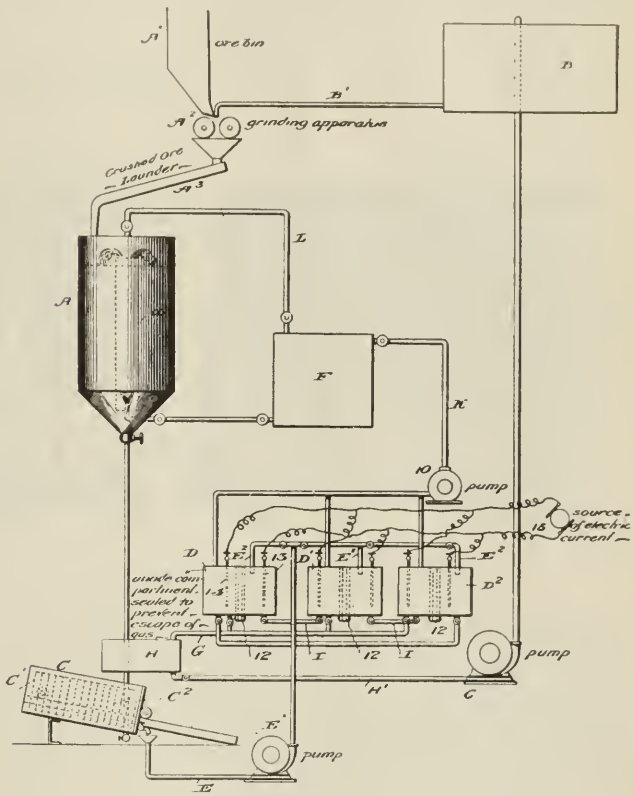


FIG. 4—PROCESS OF CHLORINATING ORES

Electrolytic Processes

Electrolytic Production of Caustic and Chlorine.—A patent issued to Mr. William M. Jewell and assigned to the Chloride Process Company of Chicago, Ill., describes a combination of gravity and diaphragm cells. In this cell for producing chlorine and caustic solution from brine, the anode liquor is heavier than the cathode liquor, and is drawn off gradually from beneath the cathode liquor which remains practically undisturbed. This is done for the purpose of keeping the solution around the anodes in motion in order to prevent formation of hypochlorite and chlorate. A longitudinal section and cross-section on end of this cell is given in Fig. 5. The cathodes are the same as the anodes with the exception of being shorter. The cathodes are represented by 23, the anodes by 19; 18 is a partition separating the anode chamber from the cathode chamber and 17,17 are other partitions dividing the whole cell into single sets. A is the chamber for caustic solution, B contains the fresh electrolyte, a saturated solution

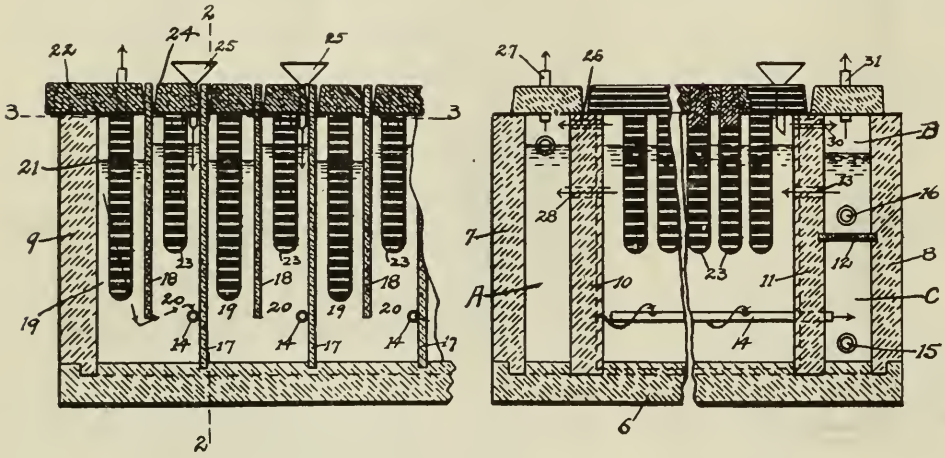


FIG. 5—ELECTROLYTIC CELL FOR CAUSTIC SODA AND CHLORINE

of brine, and C contains the spent brine, which is conducted away and replenished; 14 is a pipe through which the anode liquor flows from the cathode compartment into C, the cathode liquor not reaching down as far as this pipe, 28 is a passage for caustic solution into chamber A; 13 is a passage for conducting new electrolyte into the anode chamber, 12 is a partition separating chambers B and C. "By circulating the anode liquor, a very rapid rate of flow can be maintained without adding any appreciable amount of salt or chlorine to the cathode products, and I am able to obtain very high efficiencies both in chlorine and caustic soda production. By using anode and cathode elements arranged vertically, I also obtain much better results than when horizontal electrodes are used, as the electrode area being substantially vertical the gaseous products of the electrolysis are very readily eliminated." (1,145,593, July 6, 1915.)

Electrolytic Purification of Liquids.—An apparatus for the electrical purification of milk is described in a patent issued to Mr. James L. Goucher of New York, N. Y., and assigned by him to The New York Conveyancers Company. The feature of the apparatus is the use of vessel-shaped electrodes. The milk flows through the apparatus at a rate which is mechanically controlled. The electrical treatment is claimed to render the milk pure and sterile, and to generally improve its qualities. (1,145,862, July 6, 1915.)

An **electrical method of treating lumber,** which is claimed to greatly shorten the time of seasoning and protect the lumber from bugs and insects, is described in a patent of Mr. John P. Sullivan of Memphis, Tennessee. Electrodes are connected to the timber in such a way that the current flows along the grain. A compound consisting of salt, bluestone, alum, indigo-blue and water, applied to the surface of the wood, before applying the electrodes, is claimed to aid in the conduction of the current. The dynamo should have a capacity of 110 volts and 30 to 40 amperes. (1,146,212, July 13, 1915.)

An **electrical controlling device** which utilizes the variable conductivity of solutions is patented by Messrs. Walter J. Pike and Roy J. Sutton of Grand Rapids, Mich. In this device, which depends for its action upon the principle of the Wheatstone bridge, a solution of low conductivity may be passing through the apparatus and it may be desired to have a solution of a higher conductivity emerge. By so setting the apparatus that it is balanced when the desired solution emerges, any solution of lower conductivity sets up a current in the bridge, which closes a switch and operates a valve which supplies the necessary ingredients to bring the solution up to the required conductivity. The solutions themselves are, of course, parts of the bridge connections. (1,145,509, July 6, 1915.)

Chemical Engineering

Water Treatment.—An invention relating to the prevention of corrosion and pitting in steam boilers is patented by Mr. Charles Haythorpe of Kennington, London, England. Zinc plates as heretofore used for this purpose have proved inefficient in that they do not prevent grease deposits or incrustations, and their effect is only local. The present invention contemplates the use of plates of zinc and carbon which are maintained in close and intimate contact, forming an efficient galvanic couple, and are also arranged in good metallic contact with the boiler. It is claimed that apparatus constructed in accordance with the invention has been found sufficiently intense in its action to remove old scale and incrustation in boilers already used. Economy in cost of 30 per cent to 40 per cent is effected since fewer plates are required than with other types. (1,127,360, Feb. 2, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Sugar-House Evaporating Apparatus.—Bulletin 149 of the Agricultural Experiment Station of the Louisiana State University and A. & M. College (Baton Rouge, La.) relates to "performance tests of sugar-house heating and evaporating apparatus." The author is Prof. E. W. Kerr, who was assisted by Messrs. J. F. Gunther and W. A. Tolsten. The first part of the Bulletin contains an account of laboratory experiments made in continuation of the author's former researches of which a very full account was given in our Vol. XI, pages 333 and 611 (June and November, 1913). The final results of the laboratory work are summed up as follows:

The temperature conditions in the steam compartment

are very erratic and changeable, especially with very low steam pressure.

Air or other incondensable gases in the heating steam greatly reduce the heat transmission even with relatively low vacua. The coefficient of heat transmission* varies according to the equation $U = C(P_s/P_t)^n$, in which C is a constant, P_s the partial pressure of the steam and P_t the total pressure. The value of n seems to lie somewhere between 3 and 4. The presence of air pockets may be conveniently determined by means of thermometers in the steam compartment; good circulation and distribution of steam are important in preventing them.

The loss in heat transmission due to hydrostatic head is considerably in excess of the theoretical, and this excess is greater for short tubes than for long tubes. The loss with varying heads, other conditions being equal, varies according to a straight line formula.

Other conditions being equal, the lower the "temperature level" the smaller the coefficient of heat transmission; in other words, the lower the temperature and density of the heating steam the smaller the coefficient. The coefficient of heat transmission varies according to the equation $U = 2.25 + 17{,}500D$, where D = density of heating steam in pounds per cubic foot.

Increasing the density of the boiling liquid causes a loss in heat transmission due to the decrease in temperature fall according to the equation $y = CD^{3.1}$, in which C = a constant and D = density in degrees Brix. The total loss due to the density of the boiling liquid seems to be in excess of that due to loss of temperature fall. This may be due to lower velocity of circulation.

The vapors evolved from liquor of high density or from liquor under hydrostatic head are superheated.

The entrainment was less in a double-tube calandria than in the standard calandria, probably for the reason that the spouting action was lacking.

The coefficient of heat transmission seems to be independent of the quality of the steam. Superheated steam gives coefficients as high as those obtained with saturated and moist steam.

Within reasonable limits the coefficient of heat transmission seems to be independent of the temperature fall.

The coefficient of heat transmission is independent of the temperature of juice feed.

The coefficients of heat transmission obtained in the small laboratory apparatus were much higher than are obtained in full-size evaporators. This is probably due to better circulation, cleaner heating surface, better steam distribution and the relatively large condensation pump used with the laboratory apparatus.

The great temperature fall required in the last body of a multiple-effect evaporator is due to the combined influence of greater amounts of air, steam of lower density, liquid of higher density, also, in many cases, more foul heating surfaces than in preceding bodies.

The downtake or circulation tube was shown to increase heat transmission materially. Long tubes give better results as to heat transmission than short tubes, due to better circulation.

*For definition see our Vol. XI, p. 334.

The tests show that the double-tube and the baffle-plate calandria gave greatly increased heat transmission as compared with the standard types tested, and indicate that attention to steam distribution and the removal of incondensable gases is very important.

The second part of the Bulletin gives an account of large-scale tests of the capacity and economy of evaporating and heating apparatus in sugar factories in four chapters, relating to multiple-effect evaporators, vacuum pans, juice heater, and condensers. Rather full extracts from the chapter on vacuum pans are given elsewhere in this issue.

Air-Lift Pumping.—A resumé of air-lift pumping is given in an article by Mr. PAUL H. BERGGREEN in the *Sibley Journal of Engineering* of Cornell University for May, 1915. For this important mechanism of the hydraulic engineer, which is becoming of such importance in chemical and metallurgical practice, no accurate formulæ are available because of the numerous variables encountered. A great deal more experimental work is needed in order to establish accurate details. "It was at first supposed that in all air lifts the water was discharged because of aeration in the eduction pipe, due to the intimate commingling of air and water, as the rising air bubbles gave a constant discharge of air and water. This may be true in the case of very moderate lifts, while with a sufficient head and a large volume of water, piston-like layers of air and water are formed." The many different services to which this pump may be applied are its chief cause of success. In places where ordinary pumps cannot be used, such as pumping from great depths where fine sand is encountered, and also in such cases as conducting water a great distance and subsequently elevating it, the air-lift pump has shown itself to be very useful and its future seems to lie in the direction of high lifts, in which it shows a remarkable ease of operation wherever there is a sufficient amount of submergence available.

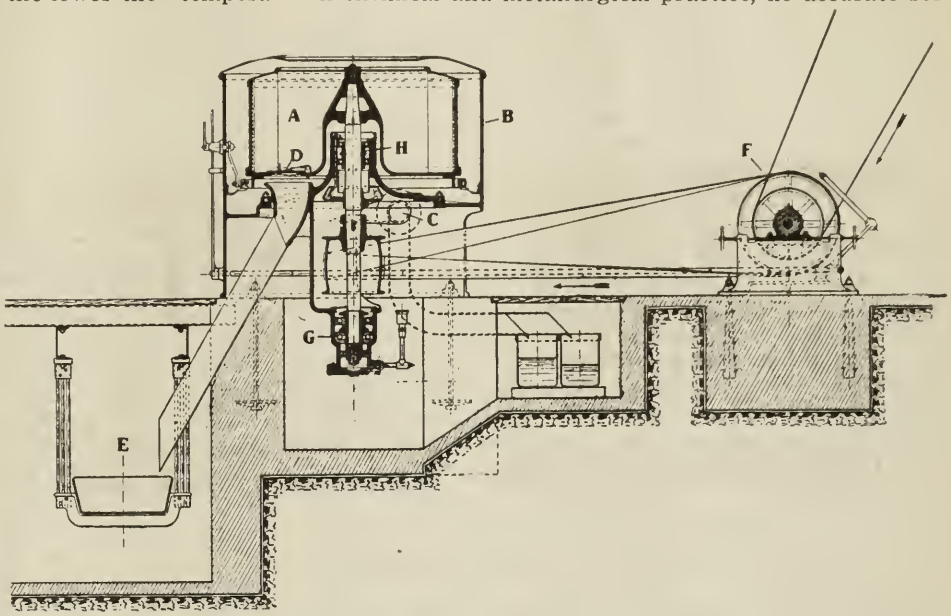


FIG. 1—UNDER-DRIVEN CENTRIFUGAL

Centrifugals.—G. BARNICK describes in *Chemische Apparatur*, June 25, improvements to centrifugal machines which are of special interest in view of the important part these machines now play in industrial chemistry. Ball-bearing machines, driven from beneath are described, together with some of the uses of centrifugals, main features of construction, and the exacting requirements which they have to meet. The advantages of the under drive, over the over-head drive, are

claimed to be: freedom of operation in charging, ease of access to driving mechanism, and the impossibility of contaminating the product with oil. On account of the high velocity (1000-2000 r.p.m.) at which a centrifugal runs, the construction must be very excellent and only the best materials must be used. The maximum load must not exceed the strain which the metal can stand. Lately, spindles have been equipped with ball bearings and this method is finding increasing application. A novel application of the centrifugal is its use in dewatering tar, the tar being freed of its water down to 1 per cent, so that it is directly applicable to felt roofing manufacture. In centrifugals for treating vaccinating serum a speed of 2000 r.p.m. is used, and the machine for this purpose must be constructed to stand a speed of 3000 r.p.m. For materials containing acid, the inside construction is made of lead, tin, copper or sometimes covered over with rubber. A machine of the under-driven type is shown in Fig. 1, in which *A* is the inside rotating cylinder, *B* the outside stationary frame, *C* the discharge pipe for liquid, *D* the discharge for solid into the receptacle *E*. *F* is the driving pulley, *G* shows the ball bearings, and *H* is an ordinary collar bearing.

Alum for Water Purification.—In an American Chemical Society paper read at the New Orleans meeting (abstracted in *Science*, July 16), C. P. Hoover described the manufacture of alum at the Columbus water softening and purification works. The process most generally employed to-day for coagulating and purifying water contemplates applying to the water under treatment a solution of aluminum sulphate. The cost of this chemical varies from $17 to $20 per ton. A plant for making alum has recently been built and put in service at the Columbus water purification plant. This is the first plant of its kind ever built at a water purification works for making alum to coagulate water, and, although it has only been in operation a short time, it has been a success both technically and economically. The process is short, simple, and inexpensive, because it consists simply in boiling bauxite with sulphate acid and applying the resultant solution to the water under treatment, thus eliminating five distinct steps in alum-making, namely, filtering, concentrating, crystallizing, grinding and redissolving. An investment of $12,000 was required for its construction, and it has been conservatively estimated that $6,000 per year will be saved the city in the cost of alum. Between 800 and 1000 tons of alum will be manufactured during the coming year at a cost of about $10.50 per ton.

Temperature of Hydrochloric Acid Formation in Evaporation of Magnesium Chloride Solutions.—Dr. H. Hof in *Chemiker Zeitung*, June 23, 1915, gives the results of a research which confirms the assertion of Casaseca, that when a pure magnesium chloride solution is evaporated the separation of hydrochloric acid takes place at 157 deg., the boiling point of $MgCl_2.6H_2O$. A paraffin bath was used for the evaporation, and it was noticed that if the surface of the solution was below the surface of the paraffin, an over-heating occurred, which caused the formation of acid at 107 deg. When the surface of the magnesium chloride was kept above the surface of the paraffin, in most cases the water could be almost completely evaporated without any formation of acid. It was also noticed that in distilling the magnesium chloride by-product from potassium chloride manufacture, the separation of acid took place at a lower temperature. This was attributed to the presence of magnesium sulphate.

Gold and Silver

Refining Gold by Miller's Chlorine Process.—In the July *Bulletin* of the Canadian Mining Institute, Mr. Ralph Pearson describes the process of refining gold at the Royal Mint, Ottawa, by the use of chlorine. The process is best adapted to the removal of silver and base metals from gold, even if present in large quantities. The requirements for the Miller process are: a constant supply of chlorine gas at a pressure of not less than 5 to 6 lb. per sq. in.; melting furnaces using either coke or oil for fuel; condensing chambers; and suitable pots, tongs, molds, etc. At the Ottawa mint the chlorine is delivered from steel cylinders holding 100 lb. liquid chlorine at a pressure of 97 lb. per sq. in. at 20 deg. C. The cylinders are housed in a cupboard that is ventilated by connection with the furnace flue leading to the condensing chamber and a pipe communicating with the outside air. The connections between cylinders and crucibles are lead pipes, rubber tubing and glass stopcocks. The desired pressure is obtained by connection with a lead receptacle like a Wolff's bottle, the third neck holding a lead pipe connected with a glass tube which is in turn connected with an enlarged lead bulb, similar to a large pipette. The lead receptacle holds sufficient water to give a column 11 ft. in height, corresponding to a pressure of about 5 lb. per sq. in. Should the pressure exceed this amount, the water is forced up into the lead bulb and the gas escapes outside the building.

From 500 to 700 oz. of the metal to be refined is charged into a clay pot and placed in the plumbago crucible in the furnace. Borax is added to form a cover about ¾-in. deep. The clay crucible has a clay cover with a slot to permit the passage of a clay pipe stem through which the chlorine is delivered to the bottom of the molten mass in the crucible. The chlorine is admitted cautiously until it passes with a steady pulsation. Dense fumes of copper and lead chlorides appear and practically all of the chlorine is absorbed. Later silver chloride is formed and floats above the gold and beneath the borax. The finishing point of the process is judged by the brown stain formed on a cold piece of clay pipe held in the fumes issuing from the pot. The fumes resulting from the chlorination and from the products of combustion are all carried through condensing chambers to a washing tower.

When the chlorination is complete the pot is withdrawn from the furnace and allowed to cool until the gold sets. Then the borax and silver chloride are poured off and separated when cold. The silver chloride is freed from some contained gold by remelting and treating with sodium carbonate, sprinkling the latter on the surface of the molten chloride. Globules of silver are reduced and sink to the bottom, carrying gold with them. The gold-free silver chloride is then treated with hot water to remove copper, which is separated from solution by precipitation on iron. The silver chloride is then reduced to metallic silver by contact with iron plates in a hydrochloric acid solution, and finally washed and melted. The fineness of the gold produced by the process will average 995, the silver fineness varies from 995 to 998. The time required varies with the amount of silver and base metals present in the gold. Thus an ingot weighing 500 oz. and containing 140 oz. base and 80 oz. silver, required 7 hours.

Treatment of Arsenical-Antimonial Sulphide Ore.—A record of experimental and practical work on the cyanide treatment of a gold ore containing arsenic and antimony sulphides is reported by Messrs. K. B. Moore and H. R. Edmands in the February *Journal* of the Chamber of Mines of Western Australia. A representative analysis of the ore follows: Insoluble, 70.04 per cent; iron, 8.3; antimony, 0.21; arsenic, 0.96; sulphur, 5.62; carbon dioxide, trace; magnesia, 2.74; alumina, 2.02; lime, 3.36; alkalies, water, etc., 6.75; total, 100.00 per cent.

A vast amount of research work was done in an effort to find a suitable method of treatment. Amalgamation and cyanidation yielded only about 50 per cent. of the gold. Concentration gave still poorer results, and the tailing yielded less than half its gold to cyanidation. Flotation gave disappointng results. Bromo-cyanide was tried without success, and preliminary treatment with NaOH did not improve matters much, as some of the gold was associated with arsenic and was not liberated. Experiments with roasting and cyaniding indicated that roasting was an essential, and a plant has been constructed in which the ore is dried, ground in a Krupp ball mill and roasted in an Edwards duplex furnace.

After this treatment the ore is mixed with oxidized ore and given the usual cyanide treatment.

It has been found unnecessary to give a perfectly sweet roast in order to get maximum extraction. Roasting must be carried far enough to liberate all gold from the sulphide, and no unaltered pyrite or arsenopyrite must be left. Ore carrying 3½ per cent to 4½ per cent sulphur retains from ½ per cent to 1 per cent after roasting, about two-thirds of which is soluble in Na_2CO_3. Samples taken half way down the roaster have given as good extraction as those taken from the discharge. The addition of lead acetate is a necessity to remove soluble sulphides.

The roast cannot be tested satisfactorily by the ordinary iodine absorption method. Owing to the frequent presence of antimony in the roasted product, which separates out on acidifying the soda extract, iodine does not give a sharp end point. The method used is to boil 20 g. of ore in 100 cc. of 5 per cent soda for one minute, decant 50 cc., acidifying with H_2SO_4 and titrate with N/30 $KMnO_4$. While this is not altogether satisfactory it gives a more definite end point and concordant results. If less than 10 cc. permanganate is required the roast is considered fair, but often a roast with far more reducing power gives quite as good extraction.

The loss of gold by volatilization has not been great, amounting to from 1s. to 2s. per ton on ore containing 53s.

In fact, the loss rarely exceeds 1s. 6d. or under 3 per cent.

Plant solution is tested for reducing power by taking 50 cc., acidifying and titrating with N/30 permanganate. Usually from 25 cc. to 50 cc. of permangante is decolorized.

Fine grinding is essential to a good extraction. The average screen test shows only about 15 per cent plus 150-mesh. A thin pulp of about 35 per cent solids gives better results than one of 45 per cent solids.

Zinc shavings were first used for precipitation, but with poor results. The authors devised a system of zinc-dust precipitation which they installed and operated with great satisfaction. The extraction has averaged over 84 per cent, with a residue of 7s. per ton. Cyanide consumption does not exceed 1 lb. NaCN per ton. The total cost is 9s. per ton, distributed as follows: Breaking and transportation, 8d.; drying, 8.5d.; ball milling, 1s. 8d.: roasting, 2s. 6d.; fine grinding sand, 6d.; agitation and vacuum filtration, 2s. 4d.; precipitation and smelting, 6d.; tailing disposal, 1.5d.

Copper

British Columbia Copper Company's Smelting Plant.—In a paper presented to the American Institute of Mining Engineers, Mr. FREDERIC K. BRUNTON describes the plant and smelting practice of this company, which operates at Greenwood, B. C. We abstract the following condensed data.

RÉSUMÉ OF FURNACE OPERATING DATA

Tons smelted per day	2,250.0
Tons smelted per square foot of hearth area, average	6.62
Tons smelted per square foot of hearth area, maximum	8.70
Tons smelted per man per day	35.70
Cu on charge, per cent	0.8 to 1.2
Cu in matte, per cent	30.0 to 45.0
Cu in slag, per cent	0.22 to 0.27
S on charge, per cent	2.00
S burnt off, per cent	85.00 to 90.00
Coke used on charge, per cent	12.00 to 14.00
Coke ash, per cent	20.00 to 28.00
Blast per cubic feet per minute	25,000
Blast, temperature	Atmospheric
Cooling water for jackets, gallons per minute	2,500
Men per 8-hr. shift	21.0
Matte, per cent of total charge	1.65
Matte, specific gravity	5 to 0
Slag, per cent, SiO_2	38 to 45
Slag, per cent Fe	13 to 20
Slag, per cent, CaO	20 to 26
Slag, per cent, Al_2O_3	6 to 9
Slag, specific gravity	3 to 2

TOTAL COSTS

The Following Costs Do Not Include Overhead Expenses, Depreciation, or Insurance

Cost per ton of smelting ore to matte	$1.18
Cost per pound of copper of converting matte to blister	0.0048
Cost per ton of copper of converting matte to blister	9.60
Cost per ton of smelting ore to blister copper	1.23
Cost per ton of copper to produce blister copper	0.105
Cost of coke per ton of ore smelted to matte	$0.851
Cost of flux per ton of ore smelted to matte	0.114
Cost of labor per ton of ore smelted to matte	0.15
Cost of power per ton of ore smelted to matte	0.033
Cost of supplies per ton of ore smelted to matte	0.03
	$1.178
Cost of coke per ton f.o.b. smelter bins	$6.00
Cost of flux per ton f.o.b. smelter bins	2.75
Cost of power per kilowatt-hour	0.0065

Concentration

Flotation Tests on Bisbee and Cobalt Ores.—An investigation of some of the variable factors in flotation undertaken by Mr. HERBERT J. FRENCH is published in the Columbia School of Mines *Quarterly*. The factors considered were (1) oil, variety and amount; (2) amount of sulphuric acid; (3) agitation, length of time and speed; (4) temperature of solution, and (5) size to which ore is crushed.

The oils tested were fish, sperm, whale, corn, cylinder, pine, pine-tar, lard and cottonseed.

The ore from Bisbee, Ariz., contained copper as chalcopyrite, chalcocite and malachite. It analyzed as follows: Insoluble, 65.1 per cent; iron, 10.9; lime, 0.9; alumina, 0.28; sulphur, 12.7; total copper, 6.04, of which 1.7 per cent was soluble in dil. hydrochloric acid. The conclusions reached as a result of the tests were: Pine-tar oil of 0.98 sp. gr. was the best frothing agent, collecting more sulphides per unit of volume than the other oils tested. Sulphuric acid in quantity approximating 0.3 per cent by weight of the water in the pulp seemed to be necessary to increase the selective action of the oil and the total extraction. Extraction improved with increase in temperature, the best condition being at 65 deg. C. Nothing shorter than 10-min. periods of agitation gave efficient flotation. Sizing the ore was necessary to secure the best results, which were obtained from material ground to from 100 to 150-mesh. The greater losses occurred in particles larger than 65-mesh.

The Cobalt ore was from the Coniagas mine, containing about 13 oz. silver per ton, mainly in the form of antimony, arsenic and sulphur compounds, with some native silver. With this ore pine-tar oil proved the most efficient flotation agent. Adding the oil in successive portions and giving longer periods of agitation gave as good an extraction with less consumption of oil.

The Silver King Coalition Mines Company is to add flotation to its standard concentrating practice at Park City, Utah. The new plant will have a capacity of 600 tons per day, and is expected to be in operation within sixty days. The Callow pneumatic process will be used.

Low-Pressure Oil-Burning Metallurgical Furnaces

Economy and efficiency in modern metallurgical work have been greatly promoted in recent years by improvements in accessory apparatus for the laboratory and mill. As an example of such apparatus may be mentioned the improved line of Case metallurgical furnaces, manufactured by the Denver Fire Clay Company, Denver. Col. These furnaces have been used with marked success in the heat treatment of metals, for assaying ores and refining cyanide precipitates, for annealing and enameling, and for melting brass and other foundry metals.

An important feature of the Case furnaces is the low-pressure oil burner, illustrated in Fig. 2. Oil is introduced usually by gravity (although high pressures can be used), and issues from the central part of the burner in a cone spray diverging at an angle of 45 deg. All air for combustion also goes through the burner, issuing from two annular rows of holes and forming a cone of jets converging at an angle of 60 deg. This produces an excellent mixture of oil and air which enters the combustion chamber of the furnace through a small opening of the same size as the face of the

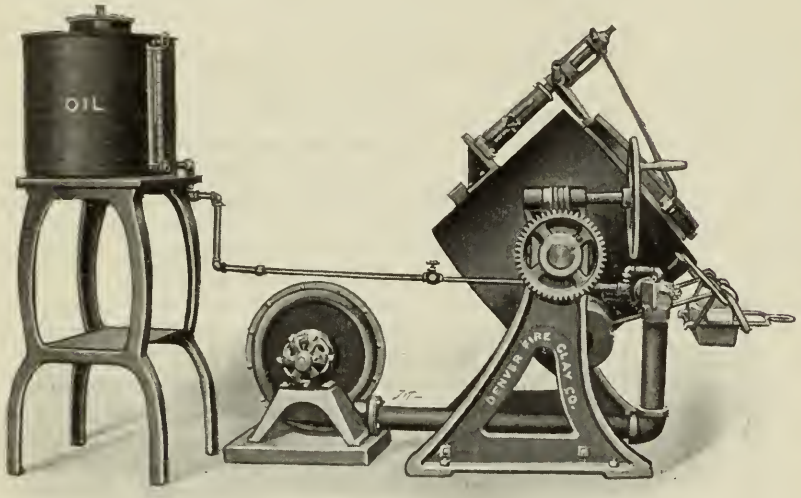


FIG. 1—OIL-FIRED TILTING CRUCIBLE FURNACE

burner, thus excluding auxiliary air. Both oil and air are under valve control, so that a mixture of proper proportion for complete combustion is easily maintained under all conditions. Air is supplied to the burner by a direct-connected motor-driven blower which runs at 3600 r.p.m. and delivers 3000 cu. ft. of air per minute at a pressure of about 6 oz. The fan has 20 blades of aluminium mounted in a cast-iron casing.

The advantages claimed for the low-pressure burner over those operating under high pressure are the freedom from noise, economy of fuel, control of air supply, perfect combustion without formation of carbon, and reduced wear and tear on the crucible and other parts of the furnace. The poor features involved in needle valves are entirely eliminated.

The burner is applied to a variety of furnaces constructed for special purposes. The one shown in Fig. 1 is a crucible furnace of the tilting type, with swinging frame to carry the mold while pouring and a cover that can be moved either vertically or laterally. This type of furnace is used for melting brass and other foundry metals, refining cyanide precipitates, and melting gold and silver bullion. Other types of furnaces are built for the heat treatment of steel, for annealing and enameling, and for assaying.

The tilting furnace illustrated, embodies many conveniences which relieve the operator of a vast amount of hard labor and protect him from the heat while pouring the charge. Between the steel shell and fire-clay lining is a layer of refractory insulating material which acts as a cushion during the expansion and contraction of the furnace, and conserves heat. The interior lining is of fire-clay tile, molded with numerous projections in the form of checker work, which support the crucible laterally. The crucible is molded with a lip that forms a pouring spout. A fire-clay stool in the combustion chamber supports the crucible from the bottom, the upper surface of the stool being channeled to permit circulation of heat around the bottom of the crucible.

The combustion chamber is below the crucible. The flame enters tangentially and complete combustion occurs almost instantaneously. The crucible and fire-clay

FIG. 2—FACE OF LOW-PRESSURE OIL BURNER

lining become highly heated as the gases of combustion rise through the checker work, and the lining radiates heat uniformly to all parts of the crucible.

The motor for the blower consumes 1½ kw. per hour. Oil consumption varies from ¾ gal. to 2 gal. per hour, depending on the nature of the work and the temperature required.

Numerous records for economy and efficiency have been established by Case furnaces. An assay furnace running 129.9 burner-hours consumed 179.8 gal. of 26 deg. Baumé fuel oil, or only 1.39 gal. per burner-hour. In another case the cost of fuel for assaying was reduced 60 per cent by the adoption of a Case furnace. An interesting comparison of fuel consumption under high-pressure and low-pressure air gave the following results: With high-pressure air 3200 gal. of oil was consumed in a month, firing three muffles; with low-pressure air the consumption was but 800 gal. for a month, and four muffles were fired.

Equally good records have been made for the tilting crucible furnace. In melting cyanide precipitate one of these furnaces used only 20 gal. of oil at 17.5 per gallon to accomplish the same results formerly attained by the combustion of 1000 lb. of coke at $16 per ton. The value of the slag was reduced from about $200 to $12 per ton. For remelting 1500 oz. of gold bullion the oil consumption at one mill was 1¾ gal. oil at 6 cents per gallon, as against the former use of 140 lb. coke at 1.12 cents per pound. In addition the time of operation was greatly reduced and the life of crucibles doubled. Another record made was the melting of 800 lb. cyanide precipitate in one hour with a fuel consumption of 1⅞ gal. of oil. In this case a saving of 66 per cent was made in fuel cost as compared with former practice.

Calibration Curve for Horizontal Cylindrical Tanks

Wherever horizontal cylindrical tanks are used for storage of fuel oil or other liquids, a simple method of calibrating becomes desirable. In Fig. 1 we show a

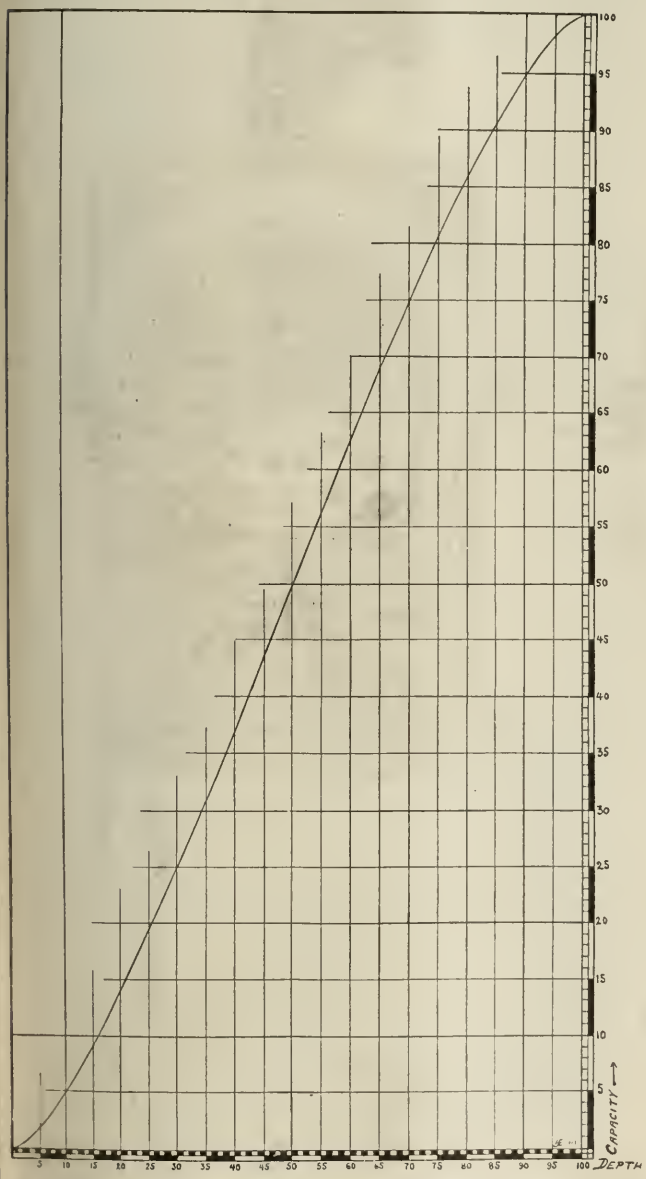


FIG. 1—CALIBRATION CURVE FOR HORIZONTAL CYLINDRICAL TANKS

calibration curve for such tanks of any dimensions, devised by Mr. H. J. Elson, Universal Iron & Supply Company, 325 Locust Street, St. Louis, Mo. The curve as here presented is somewhat reduced in size, but a full size curve can be secured on application at the address given.

The horizontal scale in Fig. 1 indicates percentage of total depth, and the vertical scale percentage of capacity. By entering the horizontal scale at the bottom with percentage of total depth, and rising to the curve, the percentage of total capacity corresponding to depth can be read at the right.

The total capacity of the tank in gallons equals the square of the diameter in feet multiplied by the length in feet, multiplied by 47, divided by 8; or, equals the square of the diameter in inches multiplied by the length in inches, multiplied by 17, divided by 5000.

To adapt the curve to a particular tank, a scale of gallons may be written in the column at the left by entering at the top, corresponding to 100 per cent, the capacity of the tank found by the above rule, and dividing it proportionately down to 0. The depth of the liquid in the tank may be taken in percentage of total depth by dividing into 100 parts a line or rod of length equal to the diameter of the tank, and then the scale can be read directly by way of the curve to gallons on the left. Or, a scale in feet and inches corresponding to the tank diameter may be put on the 0 to 100 depth scale, and the depth of liquid in the tank read from a line or rod divided in feet and inches.

Titanium-Aluminium Bronze Castings

BY W. M. CORSE

Practically every mechanical engineering handbook contains references to aluminium bronze, describing it as having the properties of good steel and in addition great resistance to corrosion. When the engineer is interested, however, in this metal and searches for a source of supply, he finds that rolled aluminium bronze can be bought from several reputable manufacturers, but he immediately encounters difficulty in securing it in the form of castings. Further inquiry develops the fact that while some foundries have made castings of this metal in the past the difficulties involved are so great that its manufacture has been practically discontinued.

The Institution of Mechanical Engineers of Great Britain, realizing the valuable properties of the copper aluminium alloys for engineering purposes, presented its eighth report to the Alloys Research Committee on this subject in 1907. This report contains a very exhaustive study of the metal commonly known as aluminium bronze and calls particular attention to the facts that it resembles a Swedish bessemer steel of 0.35 carbon to a remarkable degree and that the castings have practically the same physical properties as rolled material; this is a unique exception to the general rule.

That castings of copper and aluminium have the strength of steel and show up equally well under alternating stresses and impact tests is a fact worthy of more than passing notice.

The 10 per cent aluminum bronze has the following properties:

Ultimate tensile strength (standard test bar), 70,000 per square inch.
Elongation in 2 in., 20 per cent.
Hardness Brinell scale (500 kg.), 100.
Specific gravity, 7.5.
Weight per cubic inch, 0.27 lb.
Permanent compression under 100,000 lb. load per square inch, 12 per cent.
Coefficient of friction (Cornell University bearing testing machine), 0.0018.

It is practically non-corrodible in sea water and has a high resistance to corrosion in such chemical liquors

as the sulphite liquors in the paper industry and the tanning liquors in the leather industry.

On account of its high aluminium content the metal is approximately 16 per cent lighter than phosphor bronze and 10 per cent lighter than manganese bronze. When it is remembered that the strength of this metal is practically the same as manganese bronze and its wearing properties at least equal to phosphor bronze, the possibility of reducing weight through its use is certainly interesting from an engineering standpoint.

This metal is also analogous to steel in that it can be hardened by heat treatment. This is a very useful and unusual property for a bronze alloy to possess.

Recent letters from several prominent British manufacturers indicate that very little has been done in casting this material commercially in Great Britain. Similar inquiries in the United States reveal the fact that while aluminium-bronze castings are offered in some instances, either the quality or the price is not all that may be desired, thus practically barring this valuable metal from engineering specifications.

It is well known that small accounts of certain elements exert a profound influence on the properties of iron and steel, and it is, therefore, reasonable to expect that similar influences might be exerted upon certain copper alloys.

On this theory the Titanium Alloy Manufacturing Company of Niagara Falls, N. Y., put one of its research men on this problem with the result that it has found that small additions of titanium or its compounds exert a like profound influence on the properties of certain copper alloys, among which are the aluminium bronzes. After three years of careful research it was decided to build a foundry to manufacture bronze castings and to specialize on the aluminium bronzes. This is an important industrial achievement, and one which will enable the engineer to avail himself of these metals which have proven to be so important for many industrial uses.

That such an alloy can now be made commercially at a reasonable price is also notable.

Numerous uses immediately suggest themselves for castings having the properties enumerated above. Among these may be mentioned gears and gear wheels for high speeds and heavy loads, bearings for high-speed machinery, marine fittings exposed to sea water and parts exposed to the action of chemical liquors, parts requiring great strength and resistance to shock, and castings to withstand high pressures.

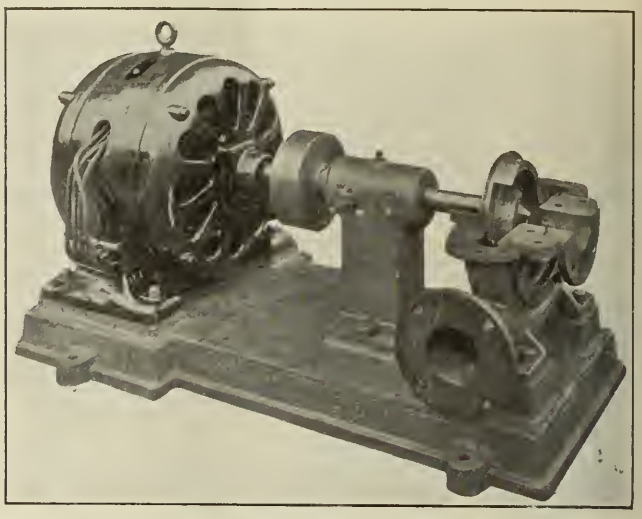
Centrifugal Pump for Thick Liquors

The cut shown herewith shows a high-efficiency type of centrifugal pump suitable for handling liquors containing large amounts of solids, chemicals, wood pulp, or gun cotton pulp solution. The impeller has very wide passages in proportion to its capacity, but its design is such that in spite of these wide passages a high efficiency is obtained, while the pump characteristic is such that no heavy overload is produced on the driving motor when the pump operates at pressures below the rated pressure, which is a condition occurring in most pumps made to handle thick liquors.

The pump has a horizontally parted case which facilitates access to the interior for convenience of inspection, cleaning and repairs. The pedestal bearing is equipped with two ball bearings operating in a housing packed with a non-fluid oil or light ball-bearing grease. They are so arranged as to carry not only the radial load but any thrust that may come on the pump in either direction. The impeller, however, is provided with a balancing ring so as to secure hydraulic balance.

On account of the large passes through the impeller, the pump is also very suitable for pumping sewage, as solids which would ordinarily choke up a small capacity impeller pass freely through the pump.

The particular pump shown in the adjoining illustrations is driven by a single-phase motor and for the purpose of keeping down the starting current a special centrifugal clutch coupling is provided, which allows the motor to come up to speed before the load comes on the



CENTRIFUGAL PUMP FOR THICK LIQUORS

motor. Either this type of coupling or the standard type of flexible coupling with steel pins and rubber bushings is furnished.

This type of pump is particularly suited for handling the nitrated cotton liquors in connection with the manufacture of gun cotton.

The pump is manufactured by the D'Olier Centrifugal Pump & Machine Company, Philadelphia, who make a full line of centrifugal pumps as well as centrifugal machines used for nitrating cotton and for general chemical purposes.

A New Assay Balance

An assay balance operated like a typewriter is a novel development in scientific instruments that is being

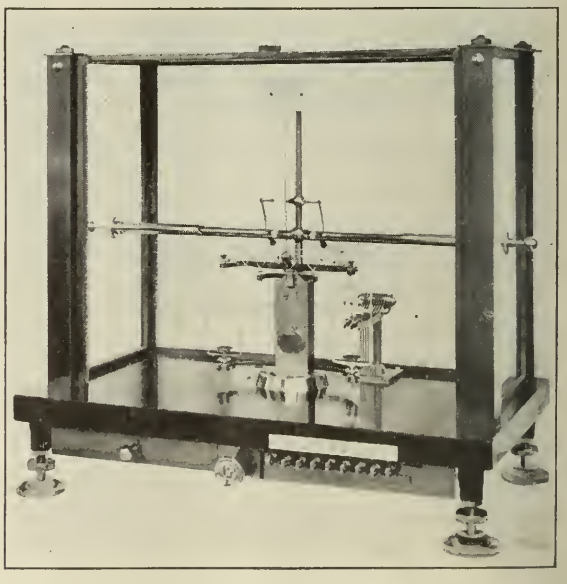


FIG. 1—A NEW ASSAY BALANCE

brought out by the Mine & Smelter Supply Company, Denver. Col. This balance is the invention of Mr.

Wilfrid Heusser, of Salt Lake City, Utah, who has for some time past been manufacturing a line of metal-case balances.

The feature of the instrument that marks a distinct advance in balance construction is the method of handling the weights, placing them on or removing them from the pan hanger. By merely pressing one or more keys which are in front of and outside the balance case, any weight or combination of weights can be deposited on the pan hanger. The balance is shown in Fig. 1, and a detail of the apparatus in Fig. 2.

The weights themselves consist of perforated discs, made of aluminium for the lighter and of platinum for

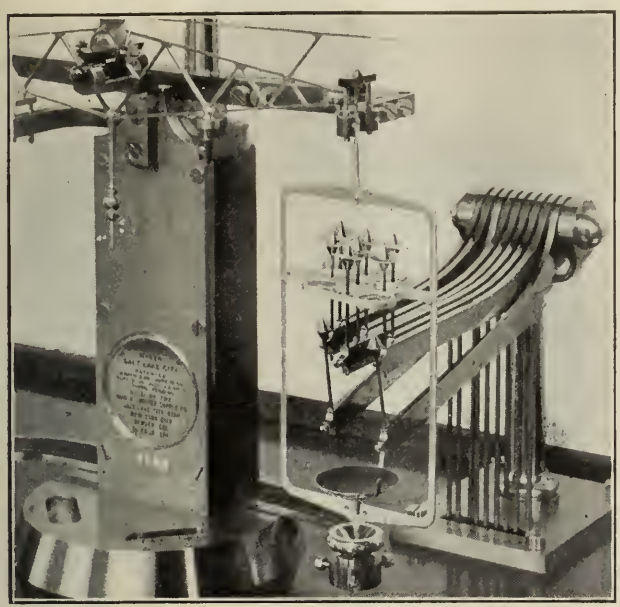


FIG. 2—MULTIPLE-WEIGHT DEVICE FOR ASSAY BALANCE

the heavier weights as is usually the case. Normally each disc is carried by one of a series of upright posts with conical tops, passing through a perforated horizontal frame which forms a part of the pan hanger. Each of these upright posts is operated by an individual key on a keyboard in front of the balance. On depressing a key, the corresponding upright post is lowered, and the weight, which is too large to pass through the perforation, rests on the pan hanger frame and registers its weight as though placed in the scale pan. In like manner, raising the key raises the upright post which, with its conical top, lifts the weight and removes it from the pan hanger frame. By this means any weight or combination of weights can be placed upon or removed from the pan hanger without opening the balance case. The device marks a distinct improvement over all previous forms of multiple-rider attachments, the object of which has been to avoid handling the weights with pincers as well as the opening and closing of the balance.

An analytical balance embodying the Heusser construction as to truss beam and metallic case has also been developed, and can be equipped with the same multiple-rider attachment just described.

Pan-Americanism

The Second Pan American Scientific Congress

BY GLEN LEVIN SWIGGETT

During the present year two great Pan American gatherings convene in Washington under the auspices of the Government of the United States. The first of these, the Pan American Financial Conference, occurred the week of May the 24th, 1915. In this conference delegates from the Latin American countries conferred with representative bankers and business men from our nation at the Pan American Union, on invitation of the Secretary of the Treasury, on financial questions of pertinent interest that must have far-reaching beneficial results to Pan American banking and commerce.

Of greater interest to the professional world, however, is the Scientific Congress that will convene in Washington beginning December 27, 1915, and concluding its sessions on January 8, 1916. Through the splendid cooperation of the Latin American countries, the second Pan American Scientific Congress, likewise held under the auspices of the United States Government through the Department of State, bids fair to be not only thus far the greatest Pan American Congress, but the most important international scientific congress ever held in the United States. The first congress of this name was held in Santiago, Chile, in 1908. It had its origin in earlier Latin American Scientific Congresses; and at the time of the Santiago congress was enlarged through the generous initiative of the Latin American countries to include the United States. This congress was well attended by visiting delegates from the United States. On its adjournment, entirely unsolicited on the part of the latter, Washington was designated as the place of meeting of the Second Congress.

This honor has a singular appeal to our nation at this time. The present European war has brought the Western Hemisphere suddenly face to face with grave economic problems that invite the serious attention of scientists and experts in the various fields of applied science. The Scientific Congress will concern itself with the constructive discussion of these as well as with the contributions in the domain of pure science wherein great advance has been made since the last congress in Santiago, Chile. Science is comprehensively defined by the congress and includes, under nine heads, such main subjects as: Anthropology, Astronomy, Meteorology and Seismology, Conservation of Natural Resources, Agriculture, Irrigation and Forestry, Education, Engineering, International Law, Public Law and Jurisprudence, Mining and Metallurgy, Economic Geology and Applied Chemistry,* Public Health and Medical Science, Transportation, Commerce, Finance and Taxation.

Washington offers unusual advantages for a congress of this nature. It enjoys an enviable distinction among the world capitals for the keen scientific interest and investigation in its various Federal Bureaus, the varied and extensive nature of its libraries and museums, the beauty of its buildings and the growing importance of detached but semi-official institutions and bureaus engaged in work of international scope. Among these none occupy a position of greater importance than the Pan American Union, the governing board of which, composed of the diplomatic representatives of the participating Latin American countries with the Secretary of State of the United States as ex-officio chairman, has signally honored the Second Pan American Scientific Congress by authorizing the use of its beautiful building for the office and sessions of the congress. The board also, in response to the request of the President and Secretary of State of the United States, authorized to act as secretary-general of the Scientific Congress the Director-General of the Pan American Union, the Honorable John Barrett, who has doubtless done more than any one American in the establishment of commerce and comity among

*The chairman of this section is Mr. Hennen Jennings.

the republics of the western world; whose good fortune it has also been to see, through the seeming accident of war, the potential promise of his great work becoming realized so soon.

The Feasibility of Continuous Causticizing

This article will be devoted to a discussion of the feasibility of adapting continuous agitation and continuous counter-current washing to causticizing soda ash by means of lime, according to the equation

$$Na_2CO_3 + CaO + H_2O = 2NaOH + CaCO_3$$

The application of these two features to metallurgical problems, especially in the cyanide treatment of gold and silver ores, has met with great success and it is believed that in other fields where the agitation of solids in liquids and the subsequent washing of the solids free from liquid containing dissolved substances is practised, the possibility of their use will be of economic interest.

Continuous operation invariably means lower labor costs and a high load factor, thus assisting in lower power costs and interest charges. Where the change from intermittent to continuous work does not sacrifice control of the operation, it results usually in allowing a large output of uniform nature.

From a mechanical standpoint the problems of a scheme for continuous causticizing are readily solved by the use of Dorr continuous thickeners and Dorr agitators.

The Dorr continuous thickener, Fig. 1, consists of a slow-moving mechanism placed in a suitable tank, by means of which the operation of settling may be made continuous through the removal of the settled material to a point of discharge and the prevention of the accumulation of solids in the tank.

It consists of a central shaft with radial arms equipped with scrapers to bring the thickened material to the discharge opening at the center of the tank by the slow rotation of the mechanism. The thick material may be

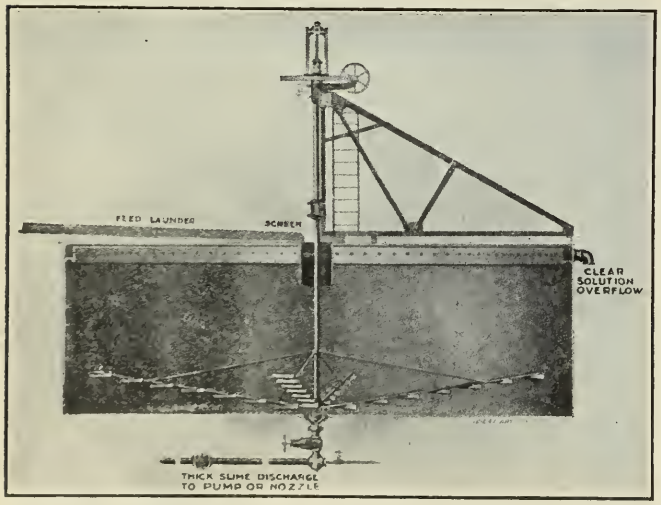


FIG. 1—CONTINUOUS THICKENER

discharged at this point into a launder, or piped to the side of the tank and raised by pump or other suitable means to the level of the overflow or higher.

The machine is arranged for raising the shaft so that the arms will not become imbedded in the thick material if the power should be shut off for any length of time. The shaft can be lowered again gradually while running.

The thickener has been operated at speeds ranging from one revolution in two minutes to one revolution in forty minutes, depending upon the nature of the solids to be settled out. The power required varies with the size of tank, but for mechanisms to be operated in tanks up to 40 ft. in diameter ½ hp. can be allowed for each machine when driving several from one line shaft.

Normal operation of the thickener causes no wear except on the worm, and many machines are operating to-day that have not cost a cent for repairs in several years. The attendance required varies with the regularity of the conditions maintained and is usually confined to lubrication two or three times per twenty-four hours.

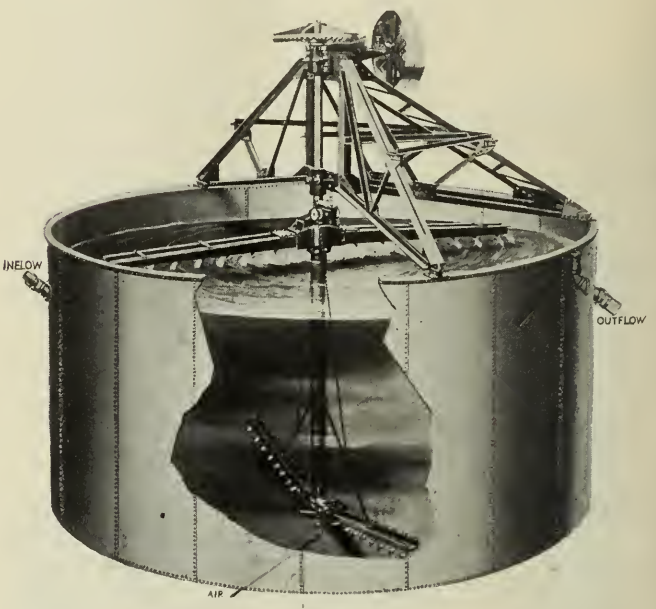


FIG. 2—AGITATOR

The illustration of the agitator (Fig. 2) will give a good idea of the machine, which is very much like the thickener, the central shaft being replaced by a pipe at the top of which distributing launders are arranged so as to distribute the material as it is raised through the pipe by means of air, the solids as they reach the bottom being raked to the center by the arms as in the thickener. The arms are arranged so that they can be raised, in which position the machine is easily started after a shutdown.

From a theoretical viewpoint the use of air in agitating caustic soda solution would be detrimental because of the possibility of reverting the caustic to carbonate, due to the CO_2 content. No data is at hand on this point, but men, both technical and practical, who are actually engaged in making large amounts of caustic soda solution, have been consulted and the consensus of opinion is that the small amount of air required, 6 to 10 cu. ft. per minute at 15 lb. pressure, would not produce a noticeable effect in practice.

The installation for a scheme such as proposed here would consist of a series of possibly two or three agitators and three or four thickeners for washing the lime mud. Referring to the flow sheet shown in Fig. 3, lime and soda ash sufficient for twenty-four hours' operation are to be reduced to ¼ in. and smaller and stored in the hoppers. Crushing becomes necessary in order to insure against the presence of unslackable lime in large lumps to cause trouble in the agitating and washing system. However, the operation could be cheaply effected while filling the hoppers each day by means of suitable crushers.

From the hoppers the lime and soda ash would be fed continuously and in the desired proportion to the first agitator of the series, either with an endless belt with

hopper-gate control or by other suitable devices, many of which are on the market. Weak solution from the washing system would be transferred directly to this agitator as indicated.

A series of agitators are advisable because it reduces the possibility of "short-circuiting," that is, the escape of lime or soda ash from the agitating system before they have had time to react. The size of the agitators in such a system is a function of the time required for the reaction to come to an end or, in other words, reach chemical equilibrium. Sufficient capacity would be necessary to allow the required time.

The heat necessary to maintain the desired temperature would be best supplied by steam coils in each agitator.

The mixture would gravitate between the agitators and finally to the first of the series of thickeners "*X*."

Overflowing from thickener *X* would be the clear caustic solution for storage and use. The lime mud as it settles out would be discharged and transferred to the succeeding thickener *Y* by means of a pump, being thoroughly mixed with the wash liquor flowing from thickener *Z* in the feed launder before entering the tank. The overflow from thickener *Y*, as previously mentioned, would be transferred directly to the first agitator and the lime mud discharged and transferred to thickener *Z*. Wash water would be introduced into the feed launder of this last thickener and mixed thoroughly with the lime mud which would be discharged from this last machine with a very low caustic soda content.

It would be feasible to feed the "mud" from this last thickener to a continuous dewatering filter and thence to calciners, so that the carbonate of lime will be reduced to calcium oxide and may be returned to the causticizing system for reuse.

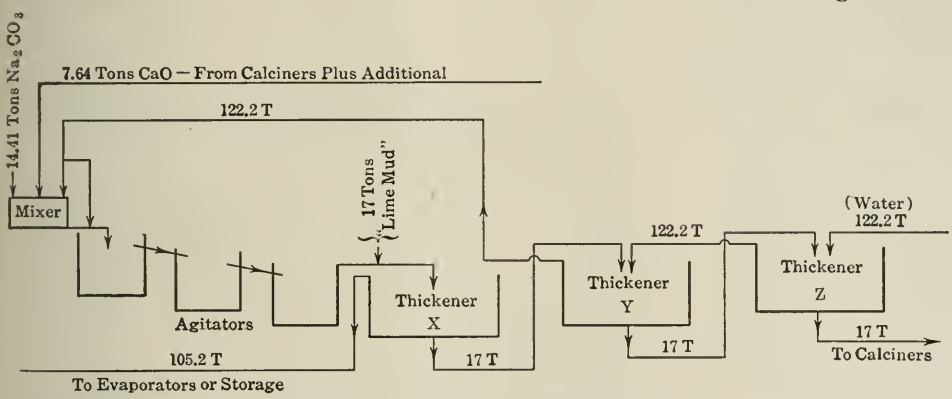


FIG. 3—FLOWSHEET OF PROPOSED PROCESS OF MANUFACTURE OF CAUSTIC SODA FROM SODA ASH AND LIME, USING CONTINUOUS AGITATION AND CONTINUOUS COUNTER CURRENT WASHING

The objects to be attained by continuous counter current washing are the dissolution under most favorable conditions of a portion of the solids treated, the separation of a solution from a finely divided solid with minimum dilution or both. It would appear that both would be expected in connection with causticizing.

Worthy of notice in such a system is the possibility of the reversible reaction involved coming to equilibrium under the most favorable conditions. It would reach this point in exactly the amount of water that goes to storage from the system as strong liquor. The washing, as will be noticed from the flowsheet in Fig. 3, yields absolutely no weak liquor, with accompanying dilution, to be added to the storage solution.

The following calculations show the results that may be expected by washing the lime mud in such a system as the one proposed. They are made along lines which have found wide favor in metallurgical work because they have given results which compare very closely with those obtained in actual practice.

T = Tons of water.

Conditions Assumed:

1. Ten tons NaOH produced in twenty-four hours.
2. Overflow from thickener "*X*" to have approximate Sp. Gr. 1.1 (190 lb. per ton).
3. Yield of NaOH, 92 per cent of theoretical.
4. Sufficient time of agitation to complete reaction.
5. Lime mud discharged from all thickeners with approximately 1 part water to 1 part lime mud.

Let *X*, *Y* and *Z* equal tons dissolved NaOH per ton water in respective thickeners.

Equating values *out* and *in* of each thickener:

1. $105.2\,X + 17\,X = 122.2\,Y + 10$ tons.
2. $122.2\,Y + 17\,Y = 17\,X + 122.2\,Z$.
3. $122.2\,Z + 17\,Z = 17\,Y$.

Then $X = 7.32\,Y = 0.0948$ ton = 189.6 lb. per ton.

$Y = 8.2\,Z = 0.0129$ ton = 25.8 lb. per ton.

$Z = 0.00158$ ton = 3.16 lb. per ton.

From the above the following results are deduced:

Liquor going to evaporators or storage contains 9.974 tons NaOH.

= 189.6 lb. NaOH per ton water.

= 8.68 per cent.

= 94.8 grams per liter.

= 13.2 deg. Baumé.

Washing efficiency = 99.7 per cent. No data are available now to bear out these figures.

A careful study of continuous counter-current decantation as practised in gold and silver metallurgy, with some knowledge of the operation of the standard type of causticizing plant as used in the soda, pulp and soap industries, leads the author to summarize in favor of an installation described as follows:

1. The personal element, so prevalent in intermittent work with the possibility of attendant losses in charging, agitating, decanting and washing, would be reduced to a minimum.

2. The reaction would proceed under the most favorable conditions for the production of a solution of a given strength, thus insuring the highest possible yield of caustic soda at all times, and the washing would be accomplished with the least possible water.

3. A relatively large amount of caustic solution of uniform strength would be made in a very compact plant. The installation meeting the requirements set forth in Fig. 3 and the accompanying assumed conditions would require a space of 40 ft. square.

4. The power consumption would be very small. Referring again to Fig. 3, 10 hp. delivered to a line shaft would be more than sufficient to run the six machines and the pumps.

5. The labor required would consist of filling the feeding hoppers. The actual attention to the plant beyond this point would consist of oiling the driving mechanisms, and this could be intrusted to a man whose principal duties were elsewhere.

It is interesting to note that the principles set forth here are the same that have largely taken the place of intermittent decantation and filtration methods in the treatment of metalliferous ores during the past few years, and are now finding their way slowly into numerous other fields of industrial work. R. W. S.

Gas Blowing Engines at the Steelton Plant of the Pennsylvania Steel Company

The advance in the design of blast-furnace blowing equipment during the last five years has been very marked. The directions of progress stand out prominently. First, rotative speeds and piston speeds have been doubled; second, complications in valve gearing have been eliminated, and, third, automatic lubrication has been perfected to such an extent that the cost of attendance and repairs has been materially reduced. All three lines of progress are represented in the two new gas blowing engines which the Mesta Machine Company recently installed at the plant of the Pennsylvania Steel Company in Steelton, Pa. These engines are the largest gas blowing engines ever built in the United States; the gas cylinders are 46 in. in diameter, the

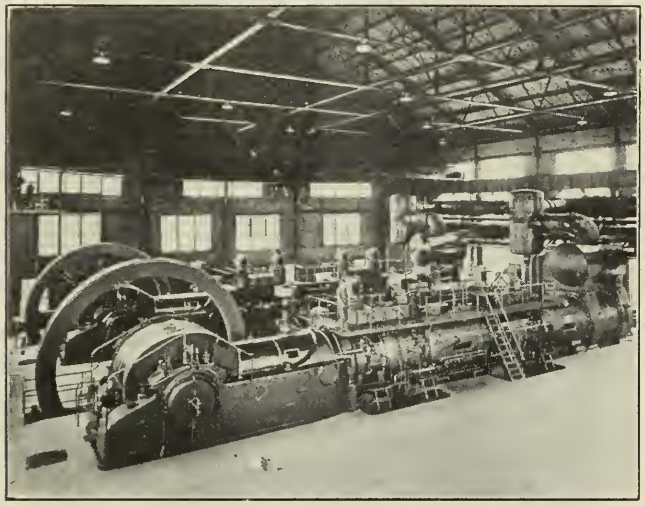


FIG. 1—GENERAL VIEW OF GAS BLOWING ENGINE

air cylinders are 84 in. in diameter and the stroke is 60 in.

As will be seen from the general view, Fig. 1, each of the engines consists of two gas cylinders and one blowing cylinder in tandem. The blowing cylinder is entirely free from valve gearing. The elimination of valve gearing has been made possible by the use of the Mesta automatic plate valves (Iverson patent) which has been so often described and is so well known that no further description is needed here.

The absence of mechanical valve gearing made possible another important step forward; namely, the placing of the blowing cylinder back of the gas cylinder, in contradistinction to previous American practice in which the blowing cylinder was placed on the opposite end of the bed plate and was connected to the main engine crosshead by rods which were arranged to clear the crank and crank pin.

Considered from an engineering standpoint the old American design is wrong. The rods connecting the main crosshead to the blowing piston necessitate a weak crank as well as openings in the bed plate which weaken the latter. Several broken bed plates of gas blowing engines can be traced directly to this design of crosshead, crank and blowing cylinder rods. In the Mesta engines this difficulty does not exist. The position of the blowing cylinder back of the gas cylinder eliminates the rods passing from the crosshead around the crank and leaves the designer free to arrange the bed plate and crank for maximum strength, rigidity and wearing qualities. Furthermore, it made possible the use of a rigid and symmetrical bed-plate construction which is identically the same no matter whether the engine be used for blowing purposes or for the generation of electric power.

The arrangement of cylinders selected by the Mesta Machine Company is the one which is used on practically all gas blowing engines in Europe. American engineers not familiar with European practice have criticised this design stating that trouble might be experienced on account of unequal expansion of the stationary cylinders and the moving rods, and, that such a long train of cylinders would cause an excessive elastic stretch at the end of the blowing cylinder. Results with the Mesta engines just installed prove that any such fears are groundless. The location of the moving parts compared to the stationary parts was carefully measured

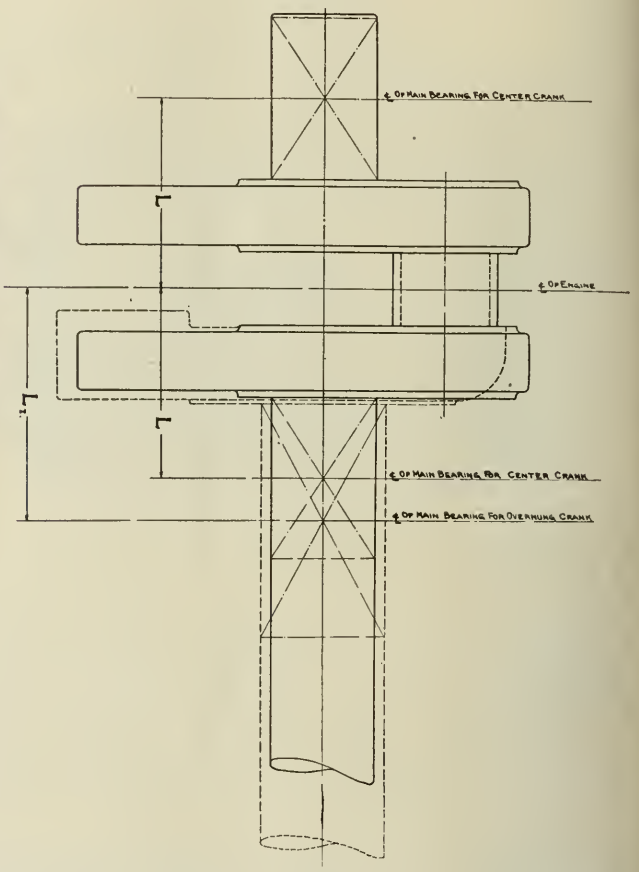


FIG. 2—COMPARISON OF CENTER-CRANK AND SIDE-CRANK CONSTRUCTION

before starting and was again measured immediately after a shutdown following several days operation. The difference in measurement was negligible. Furthermore, the total elastic stretch of the engine measured at the farthest point of the blowing cylinder is imperceptible. A five-cent piece can be balanced on edge in any direction on any stationary part of the engine. In fact, there is less vibration in these engines than is found in ordinary steam blowing engines.

With the Mesta engine the center crank was adopted because its use reduces the bending moment on the shaft to such an extent (compared to the side-crank construction) that a shaft of smaller diameter can be used and yet an engine with a much greater factor of safety results than would be possible with a side-crank construction. In order to illustrate this fact Fig. 2 was prepared in which is shown in full lines the present crank shaft of the Mesta engine and in dotted lines a side crank shaft designed with the same factor of safety. It is evident that the use of the center crank provides a more rigid and safer bed-plate construction with the same weight. In the center-crank design the

characteristic side strains found in the side-crank design are practically eliminated. While the total weights of the center crank shaft and of the side crank shaft are approximately the same, the center crank shaft is of smaller diameter, thus making a smaller opening in the bed plate and making it stronger.

The center crank eliminates one of the most objectionable features of the present-day American gas engine, namely the one-piece design of crank and crank pin. In the one-piece design of the side crank, the pin is cast integral with the crank and must therefore be of a more open-grained or spongy material than a forged crank pin. The builders of large steam engines fought consistently against steel-casting crank pins and would never have consented to the design which was used for about a decade on the gas engine. It is somewhat surprising that American engineers should have held so long to the side-crank constructions in gas engines, when a very simple calculation shows the advantages of the center crank for heavy stresses. In reversing engines for rolling mills where the stresses due to the inertia of reciprocating parts are very great, the center crank has been used for years, and, as already stated, all European gas engines are built with the center crank.

As one of the foremost builders of mill reversing engines in America, the Mesta Machine Company has had considerable experience with center-crank engines, so that it was natural for their engineers to adopt the center crank on large gas engines.

The Mesta engine follows the recent tendency in gas-blowing practice to make blowing engines of the single tandem design rather than to build twin engines. The single tandem engine is preferable from the standpoint

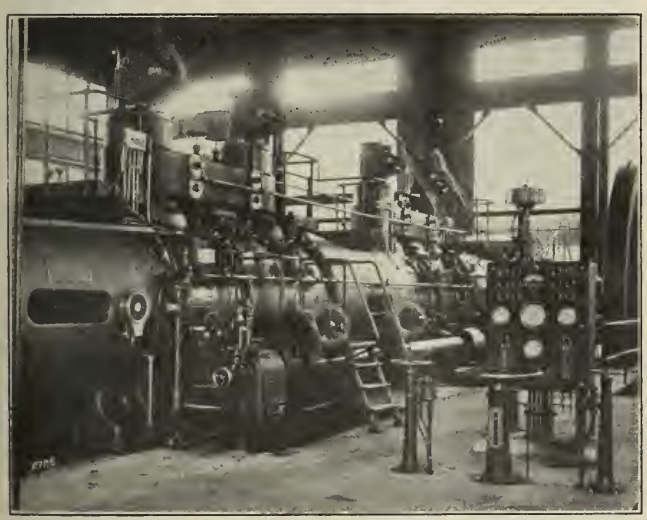


FIG. 3—SWITCHBOARD AND CONTROL HAND-WHEELS FOR GAS BLOWING ENGINES

of first cost and of reducing to a minimum the number of moving parts which require attention. There is only one crank pin and one crosshead and a comparatively small number of valve-gear parts. It is true that each part is larger, but size offers no difficulties in manufacture, so that the single tandem blowing engine will undoubtedly become the standard type.

While heretofore strenuous objection has been made to the gas engine from the standpoint of complication and a multiplicity of moving parts, it can be safely stated that the new gas engine contains a considerably smaller number of moving parts than a cross-compound Corliss engine. Indications are, therefore, that the up-keep and maintenance of this type of engine will be less than that of the cross-compound steam engine.

In the design of the gas cylinders particular attention has been given to the matter of obtaining a sound homogeneous casting absolutely free from strains caused, first, by shrinkage after casting, and, second, by the difference in expansion in service between the outer and inner walls. It was, therefore, decided to make the cylinders in halves of fairly soft close-grained air-furnace cast iron and to securely connect the two halves in the center. By the use of this grade of iron there is less chance for fire cracks to develop than with iron of a harder grade. In order to obtain a good wearing surface, the cylinders were lined with a hard close-grained iron bushing extending over the entire stroke of the piston.

The modern gas blowing engine is just as reliable as the steam engine and, in fact, more reliable. It can be started in less time and does not need to be warmed

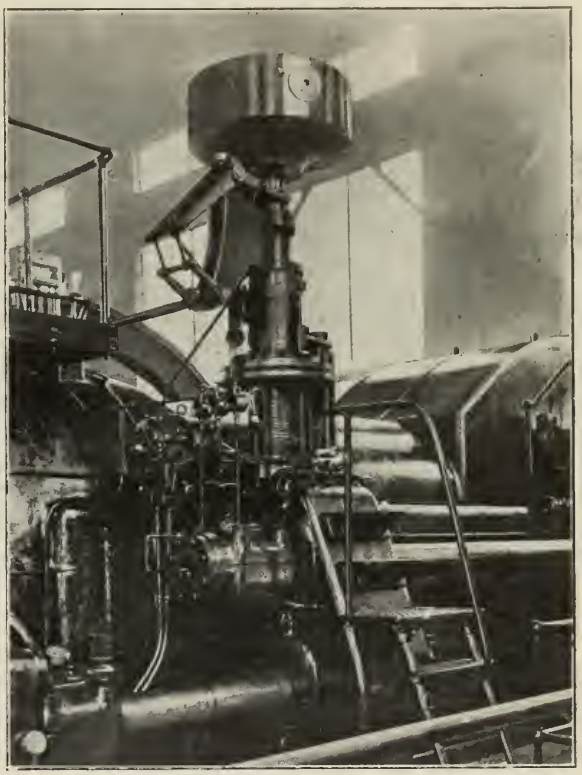


FIG. 4—GOVERNOR AND SPEED-CHANGING DEVICE

up. The Mesta gas blowing engine at the Pennsylvania Steel Company can be started and put on the furnace in less than one minute. This rapidity of handling is made possible by the concentration of all the operating levers and hand wheels on one operating stand.

Fig. 3 shows the switchboard and the control hand wheels. Fig. 4 shows the governor and the speed changing device. When the signal is received from the furnace to slow down the engine, a switch, thrown in at the control stand, changes the tension of the spring in the governor column and thus reduces the speed. As soon as the desired speed is obtained the switch is pulled out. "It beats the throttle all hollow" is the verdict of the operating engineers. The speed-changing device, which is operated by motor drive, is provided with limit switches so that it is impossible for the engineer to exceed the speed-change limit set by the designer of the engine.

Among the minor details contributing toward the success of the engine may be mentioned the exhaust valves which are not water-cooled. The valve seat is cooled and the valve itself can convey enough heat to the valve seat to protect itself. It has been said that a

gas-engine exhaust valve must withstand the action of a red-hot flame passing through it. Theoretical calculations and actual measurements show that the gases passing the exhaust valves are never hotter than 1100 to 1150 deg. Fahr., unless combustion is sluggish during the explosion stroke and continues up to the time when the gases pass through the valve into the exhaust. With a correctly designed engine and ordinary care in operation, combustion is completed before the exhaust valve opens so that water-cooling becomes wholly unnecessary. The operation of the engine at the Pennsylvania Steel Company proves conclusively that water-cooling of the exhaust valve in a properly designed blast-furnace gas engine is a needless complication. It is easily seen that the elimination of water-cooling of the moving valve does away with parts which have previously given trouble in practical operation.

The oiling system for these engines consists of two individual filters, one for each engine, the filters being placed as one unit with one large clean-oil receiver. The

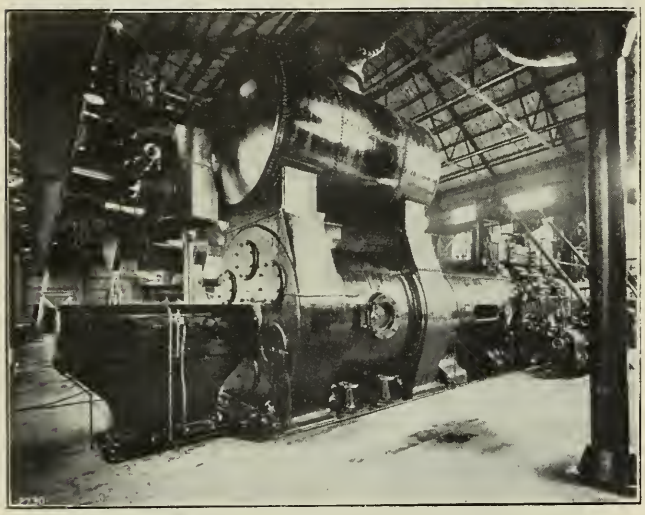


FIG. 5—SNORTING DEVICE AND AUXILIARY CLEARANCE

oil from this receiver is pumped into the system by means of a motor-driven triplex pump running at a very slow speed in order to prevent churning of the oil. This pump delivers the oil to the system at a pressure of 30 lb. per square inch and is equipped with an automatic by-pass which allows the oil to flow back into the clean-oil compartment whenever the pressure exceeds 30 lb. For the purpose of safety there is placed in the system a duplex pump which is connected up to the compressed-air line, also to the steam line, and is controlled by a Foster regulator. If anything should happen to the motor-driven pump and the pressure in the system thereby drop below 30 lb., the duplex pump will automatically start up and thus maintain a constant oil pressure in the system. The filter unit is made by the Richardson Phenix Company of Milwaukee and is capable of handling 800 gal. of oil per hour.

The lubrication of the crank pin is rather unique, in as much as the pin can be supplied with oil from two independent sources. Under ordinary conditions, oil is fed to the pin through the hollow shaft, and the supply coming from the gravity system is controlled by an extra large sight feed. In case of partial clogging of this regular supply, pressure from the oil pump can be turned directly into the pin through a large pipe, thereby flooding, cleaning and cooling it.

Each end of each cylinder is provided with three igniters of the mechanical make-and-break type. A very simple and effective device is arranged on the end of the lay shaft for the purpose of advancing or retarding all igniters. Each cylinder has its separate circuit with coils, switch, fuses and tell-tale lamp. The spark coils, as well as the tell-tale lamps and switches, are arranged on the instrument board immediately in front of the starting stand so that the operator can conveniently check the operation of the ignition system. Arrangement is made on the cylinders so that any igniter can easily be removed while the engine is in operation.

The regulating gear of the Mesta engine is exceedingly simple and efficient. Each cylinder end contains plain butterfly valves, one for gas and one for air. These valves are located immediately in front of the main inlet valve and are free to rotate without coming into contact with any rubbing surface that might cause friction. Since the vanes of these valves are very thin, there is no possibility for any impurities in the gas to collect thereon and make them "sticky."

The governor action upon these valves is such as to obtain a combination of quality and quantity regulation which has proved to be the most correct and efficient method of regulating gas engines.

Since the butterfly valves are practically balanced, it is obvious that the resistance to governor control is very small, and that the governor can act directly on the valve gear, without the interposition of an oil-relay with all its complications.

Turning again to the blowing end of the engine, the photograph shows that there is a large receiver on top of each blowing cylinder. This receiver protects the blast line from vibration. From the action of the ordinary speaking tube, it is well known that vibrations sent into a cylindrical tube are transmitted long distances without diminution of the amplitude. To damp the vibrations it is necessary to interpose receivers in the line. The closer these receivers are to the place where the vibrations are produced, the better it is for the pipe line. On the Mesta engines, there are two receivers in series close to the engine, one receiver directly on the blowing cylinder and the other a short distance away. The last-mentioned receiver acts as a distributor for the two blast lines.

For ease of handling of the engine two additional devices are of importance; namely, that for the variation of clearance space and the snorting device. Blowing engines for blast furnace service, as is well known, are subjected to peculiar conditions, as the blast pressure may at times rise to 50 per cent above its normal value. If the blowing end and gas end are properly proportioned for the average conditions the gas end is too small for the emergency condition. The Mesta Machine Company has overcome this trouble by a combination of a snorting device and auxiliary clearance. In the bed plate under the blowing cylinder are two Mesta automatic plate valves which in ordinary operation of the engine are kept open by hand-wheel operated screws. The hand wheels will be noticed under the blowing cylinder in Fig. 5.

Furthermore some of the inlet valves at each end are connected to a piston which is controlled by compressed air. Ordinarily these valves operate just like the other inlet valves, but if the small hand lever visible at the outer end of the horizontal diameter of the blowing head is turned 90 deg. the above-mentioned inlet valves are kept open. Keeping open the valve in the inlet duct permits the air to be moved in and out by the piston through the open inlet valves so that there is no air delivered. This device is made use of in starting or in changing stoves, etc. If the valves in the bed plate under the blowing cylinder are closed and the inlet valves are kept open, clearance volume is added.

The effect of clearance, as is well known, is to reduce

the delivery of air and to reduce the mean effective pressure. The reduction of mean effective pressure is made use of, if the blast pressure rises beyond 22 lb. per square inch with poor blast-furnace gas or beyond 25 lb. per square inch with good blast-furnace gas. Depending upon the amount of pressure rise above this critical pressure clearance volume is added either to one or both ends of the blowing piston. The volume of air delivered is maintained by speeding up the engine. The engine is designed for a maximum speed of 85-p.m. and has been run successfully at this speed.

Another point of considerable value to the operator of these engines is the ease with which the changing of air delivery from one blast line to another can be accomplished. In each blast-line connection from the second receiver, mentioned above, there is placed a valve operated by compressed air. These valves are controlled from the operating stand and by means of throwing a small hand lever the changing over from one line to another can be accomplished in a few seconds, whereas in older installations of this kind, it took considerable time and manual labor to make the change.

The Pennsylvania Steel Company has installed Venturi meters both in the gas and in the blast mains so that a check can be kept on the performance of the engine. Arrangements are now being made to calibrate these Venturi meters before they are put into actual service. It is expected that a thorough test for volumetric efficiency, gas consumption, regulation, etc., will be made shortly.

Army and Navy Officers Go to Private Plants

A number of army and navy officers have been permitted to resign from the public service to engage in work for private plants turning out arms and ammunition. Among these have been Lieut.-Col. O. C. Horney, U. S. A., formerly in charge of the Picatinny Arsenal; Major William A. Phillips, U. S. A., formerly in charge at the Sandy Hook Proving Grounds; Naval Constructor William E. Ferguson, U. S. N., and Naval Constructor John E. Otterson, U. S. N.

The resignations were held up several weeks, pending a conclusion as to policy by the Government. So far as the army officers are concerned, Secretary Garrison consented to the withdrawal of his officers on the theory that the safety of the United States might eventually rest upon the adequate development of the country's commercial gun and ammunition factories.

So far as the naval officers are concerned, Secretary Daniels took the position, without the announcement of a policy, that the officers in question had fulfilled agreements to serve at least eight years in the service of the United States, entered into when they began their studies at the Naval Academy. Secretary Daniels has always denied that naval officers, after being educated at the government's expense, have the right to resign.

All the officers are to receive salaries far exceeding those paid by the United States Government. In one case this is as great as five times as much as the Government salary, plus a bonus.

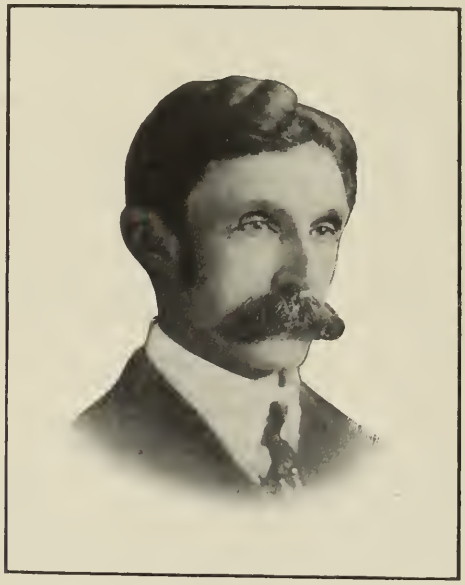
The army officers are to superintend the erection of new plants. Colonel Horney is to be employed by the Aetna Explosives Company. The naval officers are to enter the employ of private shipbuilding plants.

Obituary

Gail Mesereau died on July 14 in Cayuga, N. Y., of cerebral meningitis, superinduced by poisoning by noxious gases. He was a distinguished technologist and a popular chemist. He was born at Cayuga, N. Y., Sept. 9, 1879, was educated at Cayuga, Auburn and Syracuse, and graduated from Columbia University in 1903 with the degree of B.S. For two years he was chemist to the Susquehanna Dye and Silk Works at Williamsport, Pa. He was successively silk chemist, consulting chemist to the Panama Canal Commission, chief chemist Standard Oil Co. of New York, and consulting chemist and chemical engineer. At the time of his death he was engaged in the manufacture of explosives. He was at one time president of the Columbia University Chemical Society. Was a member of the Chemist's Club, the American Chemical Society, the Verein Deutscher Chemiker, and other scientific organizations.

Joseph Austin Holmes

Dr. Joseph A. Holmes, Director of the United States Bureau of Mines since its organization five years ago, died in Denver, Col., July 12, aged fifty-five years. While the news of his death will come as a shock and surprise to those who knew nothing of his condition, it was not unexpected by his co-workers and intimate friends. About a year ago he was persuaded to relinquish the active direction of the Bureau and go to Fort Bayard, N. M., for a prolonged rest. His recuperation was slow, however, and after a severe setback he was brought to Denver last May.



THE LATE JOSEPH A. HOLMES

Joseph A. Holmes was born at Laurens, S. C., in 1859. His early education was received in the South, but later he attended Cornell University, graduating there in 1880. In 1881 he was appointed professor of geology and natural history in the University of North Carolina, remaining there for ten years and continuing for some time thereafter as a special lecturer. For three years following his professorship he was State Geologist of North Carolina. When the St. Louis Exposition was held in 1904 Dr. Holmes was chief of the Department of Mines and Metallurgy. Following this engagement he was placed in charge of the laboratory. of the U. S. Geological Survey for testing fuel and structural material, and was later made chief of the technologic branch of the Survey. When the Bureau of Mines was organized in 1910 Dr. Holmes was appointed Director and continued in that position to the time of his death.

All who knew Dr. Holmes were acquainted with his

habits of industry and incessant activity. Personal sacrifice was not considered or allowed to interfere with the numerous duties which he took upon himself. His official travels took him over the entire United States and to Alaska and Panama, and gave him a wider acquaintance among mining men than falls to the lot of most officials. To the end he maintained an active interest in the conservation of life and resources in the mineral industry, and his work to promote the safety and health of others stands as a monument to his memory. Although frequently cautioned to conserve his own health and energy, his friends found it impossible to prevent him from actually sacrificing himself to the cause to which he was devoted. Suffering exposure and undergoing hardships in Alaska and in mines, he contracted tuberculosis, which caused his death. He is survived by his wife, two sons and two daughters.

Technical Section of the American Paper and Pulp Association

A characteristic sign of the times is the formation of the Technical Section of the American Paper and Pulp Association. It has been organized for the consideration of problems affecting cellulose and paper chemistry, machine design, and the various branches of mechanical and chemical engineering which engage the study of paper mill operators.

The executive committee consists of Mr. Henry E. Fletcher (Fletcher Paper Co., Alpena, Mich.), chairman, and Messrs. W. G. MacNaughton (Nekoosa-Edwards Paper Co., Port Edwards, Wis.), and Ernest Mahler (Kimberly-Clark Co., Neenah, Wis.). Mr. Thomas J. Keenan, editor *Paper*, is secretary-treasurer. The committee on publication consists of Messrs. Charles F. Rhodes (International Paper Co., Glen Falls, N. Y.) and Henry Oberman (Hammermill Paper Co., Erie, Pa.).

Personal

Mr. **J. V. N. Dorr** spent part of the month of July in Colorado and will be in San Francisco in August.

Mr. **Frank R. Farnham** has joined the staff of Walter B. Snow, Publicity Engineer and Advertising Agent, Boston. Mr. Farnham was previously with the McGraw Publishing Co., in charge of the copy service department.

Mr. **N. L Heinz** is engaged in designing and erecting the new zinc and acid plant for the American Steel & Wire Co. at Donora, Pa.

Mr. **Archibald Jones**, who has been general manager for the Bartlesville Zinc Co., Bartlesville, Okla, has been appointed to a similar position with the American Zinc & Chemical Co., at Langeloth, Pa.

Mr. **Milo W. Krecji**, formerly metallurgist at the Boston & Montana Reduction Works of the Anaconda Copper Mining Co., has been promoted to the position of assistant superintendent. He is succeeded in his former position by Mr. E. S. Bardwell, who has been general foreman of the concentrator.

Prof. **Charles E. Locke**, of the Massachusetts Institute of Technology, was a recent guest of "Tech" alumni at Denver. After an informal dinner Professor Locke gave an illustrated lecture on the new home of the Institute, which is expected to be occupied in September, 1916.

Mr. **W. E. Lummus**, of Boston, was in New York and reported great activity in the distillation field.

Mr. **J. B. McKennan** has been made general manager of the Colorado Fuel & Iron Co., and is succeeded as manager of the Minnequa works by Mr. **F. E. Parks.**

Mr. **H. M. Montgomery**, Chairman of the Chicago Section of the American Society of Mechanical Engineers has been elected vice-president and director of the Powdered Coal Engineering & Equipment Co. of Chicago. This company is preparing elaborate plans for the construction and equipment of a large demonstration plant and research laboratory in Chicago where working demonstrations of the adaptation of powdered coal as a fuel to all forms of furnace heat production will be carried on under engineering observation, aided by every influence that scientific research can bring to bear on the production of perfect combustion.

Mr. **Irving A. Palmer** has been appointed superintendent of the Altoona, Kan., zinc smelter of the U. S. Smelting, Refining & Mining Co.

Dr. **William B. Phillips** has been elected president of the Faculty of the Colorado School of Mines and will assume the duties of his office Aug. 1. For some years past Dr. Phillips has been engaged as director of the Bureau of Economic Geology and Technology of the University of Texas.

Mr. **A. M. Plumb** has returned to the Denver office of the American Zinc Ore Separating Co. after a stay of several months at the ore-dressing plant at Plattville, Wis.

Mr. **F. W. Sherman** has resigned his position as superintendent of the Daly-West mill at Park City, Utah.

Book Review

The Cementation of Iron and Steel. By Dr. **Federico Giolitti.** Translated from the Italian by **Joseph W. Richards** and **Charles A. Rouiller.** Price $4.00 net, New York. McGraw-Hill Book Co.

In seeking for words to describe the place which this book occupies in the literature of the industry one may say that what has been done in the past thirty years for our knowledge of the physical properties of steel by Tschernoff, Sorby, H. H. Campbell, and Howe, has been done for the cementation of steel by Giolitti. The empirical rule of thumb which formerly controlled the processes of cementation and case hardening, Giolitti has converted into scientific formulæ; what reliable information existed previous to his work, he has collected and classified; gaps in our knowledge have been filled by his extensive and skillful researches, and the result has been presented in a book which is comprehensive, legible, lucid and intelligible to anyone with even a foreman's knowledge of the trade. It can be conservatively said that the importance of this work is such that the experienced practitioner might now tell by a study of the efficiency in any cementation plant whether those in authority were, or were not, familiar with Giolitti's book.

The work is divided into two parts, of which the first discusses the chemical and theoretical side of the subject upon which the industry itself is based, while the second part describes the industrial application of the process of cementation and gives those rules and hints for the control and guidance of the process which are most useful to those who are practically engaged in carrying on the operations.

The translation of the book by Richards and Rouiller renders it in a form in which the English-speaking public may secure the result of Giolitti's work without the least difficulty in instant comprehension, or fatigue as a result of continued reading. B. S.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, SEPTEMBER 1, 1915 No. 9

Published Semi-monthly on the First and Fifteenth of Each Month by the

McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.
A. E. Clifford, Secretary. John T. DeMott, Treasurer.

239 West 39th Street, New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Colo.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for September 1, 1915

EDITORIAL:

Statement by James H. McGraw..... 521
Present Importance of Metallurgy..... 522
Flexibility in Finished Steel Production..... 522
Chemical Engineering 523
Steel Capacity and Demand..... 523

READERS' VIEWS AND COMMENTS:

Adjustment of the Direct Electric Lighting Current to Electro-Analysis. By Edmund J. Kauffman..... 524
Platinum Boats for Carbon Determination by the Direct Combustion Method. By H. F. Siever..... 525
Newspaper Chemistry of Platinum..... 525
Western Metallurgical Field 526
The Non-Ferrous Metal Market 527
The Iron and Steel Market 527
Los Angeles Meeting of the American Institute of Chemical Engineers 530
Roasting and Leaching Concentrator Slimes Tailings. By Lawrence Addicks 531
Mestastability of Metals. By A. Vosmaer..... 535
Chemical Principles of the Blast Furnace. By J. E. Johnson, Jr. 536
Manchester Meeting of the Society of Chemical Industry.... 543
Industrial Energy as a Military Weapon. By J. R. Finlay... 547
Condensers for Evaporating Apparatus. By E. W. Kerr..... 551
The Electric Furnace for Reheating, Heat Treating and Annealing. By T. F. Baily..... 558
The Current Status of the Borax Industry. By Samuel H. Dolbear 564
The Electric Furnace in the Foundry. By William G. Kranz. 565
Synopsis of Recent Chemical and Metallurgical Literature 566
Recent Chemical and Metallurgical Patents..... 569
Callow-Pneumatic Process of Flotation..... 571
Magnetic Separation of Zinc-Iron Sulphide Ores..... 573
Titanium 573
National Exposition of Chemical Industries..... 574
Supply of Manganese Ore and Ferromanganese Statistics.... 575
Personal 575
Obituary 575
Digest of Electrochemical U. S. Patents..... 575
Book Reviews 577

From now on "Metallurgical and Chemical Engineering" will be published semimonthly, on the first and fifteenth of each month. The change from a monthly to a semimonthly has been forced upon this journal by the rapid industrial development of the fundamental idea of which it has been the journalistic exponent—that for the future development of engineering a sufficiently broad and comprehensive basis can only be obtained, if the chemical viewpoint is considered of equal importance for the evolution of our industries as the mechanical and physical viewpoint has been in the past in its application to mechanical, mining and electrical engineering. While the general public has been slow in recognizing the enormous importance of this fundamental idea, the creative power of this idea has been perfectly obvious to those who look below the surface of things. Manifestations of this idea in the economic life of this country are the evolution of the electrochemical industries, the emancipation of the metallurgist from the mining engineer, the dissociation of the chemical engineer from the chemist, and the quiet, steady, healthy, irrepressible growth of industrial undertakings in many phases of metallurgical engineering and chemical engineering—all achievements of hardly more than the last decade. The whole evolution has now accumulated such a momentum that its development is rapid and its influence grows daily broader. That the calamity of the European war has opened the eyes of the American public to the dependence of all our industries on chemistry and metallurgy, is purely incidental. The evolution of metallurgy and of chemical engineering as new engineering professions independent of mining and chemistry has been going on peacefully and logically these last ten years and has left its marks on the whole industrial development. And the American chemical and metallurgical industries are firmly established, rapidly growing realities. To those responsible for the conduct of this journal this evolution has been a subject of intense gratification, but also a source of embarrassment in the endeavor to do justice to the situation, until it has now become evident that the needs of the profession and of the industry which this journal endeavors to serve can no longer be taken care of properly in a monthly publication.

With the change to a semimonthly we wish to attain two objects—first, to cover more intensely and more completely the well defined field of this journal, and second, to do it more promptly, to give "news value" to the technical news we print. The change to a semimonthly means no change in policy, no fundamentally new viewpoint, but it shall mean more intense cultivation and greater promptness such as may be expected

from a live technical newspaper, but is impossible of fulfillment in a monthly. We believe that the service which the metallurgical and chemical engineering field —the profession and the industry—have a right to expect from the representative journal in the field, can be rendered properly in a semimonthly, and in trying to render it we are sure of the support and good-will of our readers which we have so fully enjoyed in the past.

To me personally, the growth of this journal from small beginnings in 1902 has been a constant source of pleasure. It seems eminently fitting that the publishing company which publishes the "Electrical World," the "Engineering Record" and the "Electric Railway Journal" has been instrumental in giving to the glorious new professions of chemical and metallurgical engineers their technical newspaper. I pledge my hearty support to "Metallurgical and Chemical Engineering" in its endeavors to work more strenuously than ever toward the realization of its ideals, and on its entrance into the semimonthly field I bid it God-speed.

James H. McGraw.

The Present Importance of Metallurgy

Not in years has the spirit of optimism been so prevalent in the western mining industry as at the present time. The unprecedented prices for metals and the prospect that those prices will be maintained have operated to loosen the purse strings of that part of the investing public that knows the hazards as well as the profits of mining. But the most significant feature of the revival is the fact that those who are anxious to engage in mining are no longer frightened at the prospect of encountering a difficult metallurgical problem. The rapid progress in metallurgy in the past few years has inspired confidence and has aided wonderfully in the extension of the mining industry. As expressed by one engineer: "If I can only find the mine, I have little doubt of being able to develop a suitable treatment process."

If the past few years have been lean in mining, they most assuredly have been fat in metallurgical research and development. Our time has been spent to good advantage. And now that our opportunity is at hand we are able to make full use of the knowledge that we have been at such pains to gather. In the absence of the discovery of new mining districts operators are looking for neglected opportunities in the dumps and mines of abandoned districts, confident that the metallurgical difficulties and handicaps of the past can be readily overcome.

A good example of this kind of revival, based wholly on the development of modern metallurgy, was chronicled in our last issue. To bring life and activity to a district that has been abandoned for a score of years is an achievement of which the metallurgical industry may well be proud. Doubtless there are other such opportunities. They may lack the spectacular features of those projects that are conducted on a huge scale, but they afford a chance to put into practice the special knowledge that has been developing for several years.

Flexibility in Finished Steel Production

The steel industry has been giving a remarkable exhibition of its flexibility as to the production of different descriptions of finished steel. The engineers have been calling for specialty mills, and it really would seem from a scrutiny of the majority of large steel plants that specialization has been carried very far, yet despite the great change that has occurred in the distribution of demand among the various finished steel products the steel mills appear to be fully equal to the emergency. They appear to be able to operate at capacity and yet to furnish the buying trade with respective proportions of bars, plates, sheets, skelp and what-not that are demanded.

A part of the flexibility that is exhibited is due to the fact that from one product to another one mill begins before another has altogether left off. Thus the regular sheet mill can roll fairly heavy gages, while the jobbing mill can encroach both upon the sheet mill and the light plate mill. Each mill performs best on its specialty, but is not altogether limited to it. In merchant or bar mills the different sizes of mills yield their best service in a relatively narrow range of sizes, but are not confined to those sizes. Almost since there have been rail mills and billet mills there have been built "interchangeable" rail and billet mills, which could change from the one product to another merely by changing rolls. In the past few months still greater flexibility has been secured in certain rail mills, by changing rolls and adapting them to the production of large steel rounds, for which there has been a very heavy demand. The demand for ordinary merchant steel bars has been abnormally large, but thus relieved the bar mills are able to keep up with their orders fairly well.

Apart from the considerations just mentioned, the apparent flexibility of steel-finishing departments is maintained in large part by there being a very considerable excess in steel finishing over steel-making capacity. Probably at no time in the history of the steel industry, as now constituted, has it been possible to find sufficient steel to operate all finishing departments at 90 per cent of their real capacity. As new plants have been erected they have usually started with insufficient finishing capacity, and have appeared in the market as sellers of billets or sheet bars, but it has been almost the invariable history for such plants to add finishing mills one after another, so as to have reserve finisihng capacity and be able to catch the market in its various twists. Local conditions determine largely whether or not this is a wise policy. There is some investment lying idle, or but partly employed, in a plant that is making steel at capacity but has an excess of finishing capacity, but if it were not thus aligned it would at times have idle steel-making capacity instead. In the case of the plant the United States Steel Corporation is completing at Duluth, strictly local conditions obtained, and this plant was laid out to give the finishing mills a wide latitude in the character of the product they could turn out, for the demand in the far Northwest is yet to be gaged, and the plant is built largely against the demand of the

future. Such flexibility, of course, is purchased at the expense of an increased cost per ton, but in a practically isolated plant the first thing to do is to arrange to fill such demand as develops.

Chemical Engineering

The announcement of Columbia University on the establishment of a separate department of chemical engineering, independent of the department of chemistry, is but another characteristic sign of the times. The only other American university where this experiment has been made before, is, we believe, Wisconsin. Yet it is a most natural and logical development when once the conception of chemical engineering, its function and scope, are fully understood. No one would now suggest that for the training of mechanical engineers and electrical engineers the department of physics is sufficient. Yet the analogy with chemical engineering is as perfect as analogies can be, and the really interesting feature of the Columbia announcement is that it is Columbia University which takes this step.

Another characteristic sign of the times is the emphasis laid on chemical engineering in the series of able papers at the recent annual meeting of the British Society of Chemical Industry, reported elsewhere in this issue. Particularly Dr. Beilby's paper will be found most interesting and suggestive in defining the chemical engineering viewpoint.

Steel Capacity and Demand

The prince and pauper industry, otherwise the steel-making industry, has passed through its period of depression and entered upon a period of prosperity. It is either a feast or a famine, a chill or a fever. There are reasons. Two of them are, first, that inasmuch as steel is employed rather than consumed, the quantity that is put into employment in any one year may vary within wide limits, and second, that inasmuch as stocks of steel are carried by buyers rather than by producers the market demand increases or decreases more greatly than the actual employment or consumption, as buyers increase or decrease their stocks.

A little reflection and study of the statistics will indicate that there is in existence in the United States fully 400,000,000 tons of iron and steel, all performing more or less useful service, and naturally the additions to the store from year to year are not uniform. In 1905, 1906 and 1907 there were very large additions, since by far the major portion of the steel made in those years could be traced directly to large employment operations, in bridges, buildings, rails, cars, locomotives, etc. The present demand, however, does not run so largely in that direction. There is, for example, a large demand for steel for war purposes, where the actual employment covers in some instances only a few seconds of time. The second of the two causes noted above for the steel industry being either prince or pauper is the more potent at this time. A large tonnage of steel is distributed by jobbers, while another very large tonnage is purchased from the mills by manufacturers of hardware, machinery, motor vehicles, agricultural implements, etc. These buyers, jobbers and manufacturing consumers carry such stocks of the various sizes and descriptions of steel as they consider adequate to the smooth conduct of their business. When the steel mills are slack of work they can make very prompt shipment against new specifications, not hesitating to change rolls, for instance, from day to day or even more frequently. When they can accumulate a tonnage ahead they arrange their rolling schedules to much better advantage, and thus almost overnight, in a trade revival, the buyer of steel who has hitherto been able to count upon shipment in two or three days may be confronted with a delivery promise of a month or longer. Promptly he increases his specifications, for to conduct his business satisfactorily he must carry much larger stocks than formerly. The steel trade is now in the condition just indicated.

The steel industry may have difficulty in attaining the stage of operating at capacity, and indeed for almost two years there has been more or less idle equipment, but once the capacity stage is reached the full operation lasts for quite a while. In the past seventeen years there have been five such periods of marked improvement, resulting in capacity operations, full employment being reached in 1899, 1902, 1905, 1909 and 1912. The shortest period of full employment was that in 1912-13, approximately a twelvemonth, while the longest was that centering in 1906, about three years. In the shorter periods the chief influence causing the demand upon the mills to exceed the average was the desire of buyers to replenish stocks. In the longest period the chief influence was an actual consumption quite above the normal.

Each time the iron and steel industry reaches a stage of full employment the production is found to be much in excess of the best rate previously attained, and naturally by the amount that capacity has increased the period of full employment is shortened. The condition at the present time is therefore distinctly peculiar in two respects—in that the present capacity is only slightly greater than that of two years ago, when the industry was fully employed, and in that there is not likely to be much disposition to increase capacity in the next year or two. There has been little increase in blast furnace capacity in the past two years, and while there has been considerable increase in open-hearth steel making capacity, it is very doubtful whether the real steel making capacity of the country has been increased by anything like a corresponding amount, when there is question as to there being adequate supplies of pig iron and scrap, and there is less call for Bessemer steel than formerly. As to new construction at this time, a labor shortage is in prospect, and from this and other causes construction is likely to be expensive, while on account of financial conditions during the war, and the prospective release of much steel-making capacity at the close of the war, steel manufacturers are likely to hesitate in the matter of making very large increases in their productive facilities. Thus the period of full employment of steel-making capacity may this time prove to be unusually long.

Readers' Views and Comments

Adjustment of the Direct Electric Lighting Current to Electro-Analysis

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The broadening of the field of usefulness for electro-analysis in the metallurgical laboratory by the introduction of agitation of the electrolyte, and also by the application of the theory of graded potentials, has been of great worth to the chemist and to the manufacturer. However, the writer believes that sufficient stress has not, as yet, been put upon the substitution of accurate, clean-cut electrolytic determinations for older and considerably cruder methods. This especially applies to the average laboratory engaged in work on the metallurgy and chemistry of iron and steel.

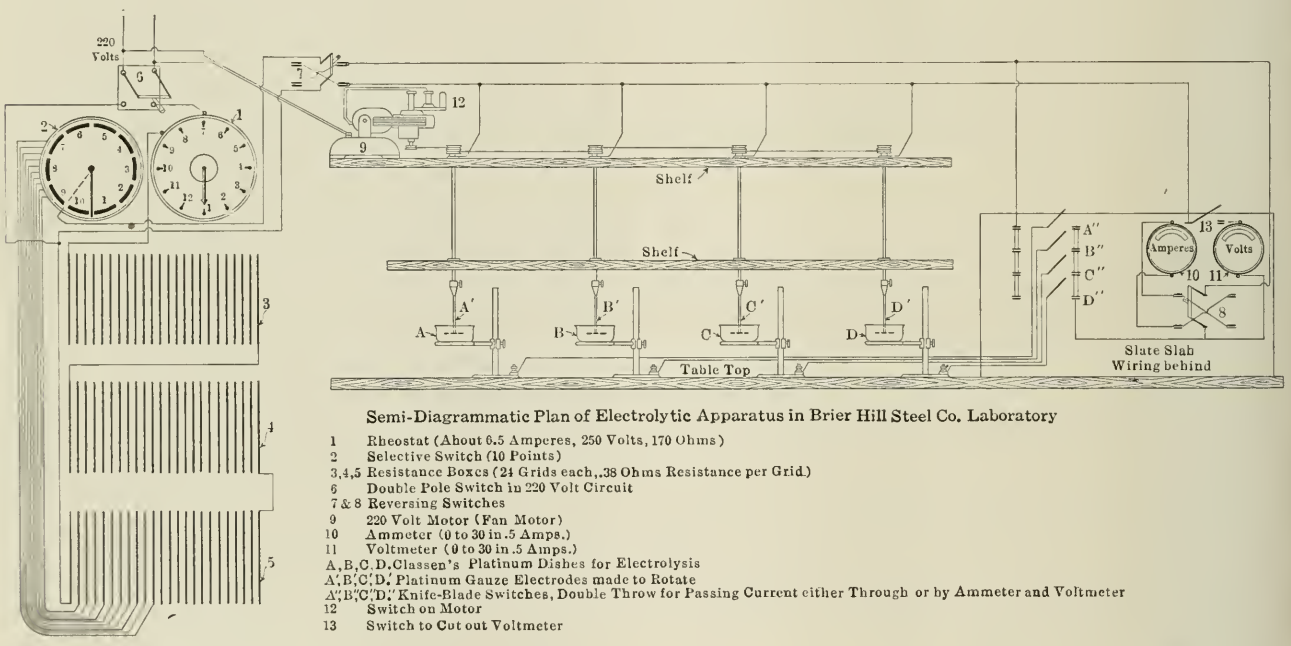
In order to do what he can in furtherance of a broader application of electro-analysis as applied to routine work, the writer wishes to describe an arrangement of apparatus which has saved time, labor and expense, with a large gain in accuracy and satisfaction.

It was decided, when designing the electrolytic apparatus about to be described, to do away with the troublesome and expensive storage battery, utilizing instead the direct electric lighting current. At the same time it was decided to retain the advantage of simple and accurate voltage regulation possessed by the storage battery. It was not desired to use the familiar and inconveniently crude lampboard resistances, so the following was evolved.

The direct current, 220 volts in our case, is led through a suitable rheostat in series with three resistance boxes of the grid type; then by means of a selective switch suitable shunts are established, the voltage of these shunts being that of the drop in potential between the shunt connections. By manipulating the selective switch and rheostat in conjunction with each other, any voltage from 0.1 volt up to that desired may be reached, the current, measured in amperes, obeying Ohm's law according to $C = \frac{E}{R}$.

The accompanying sketch will explain the arrangement so that any electrician can easily install the apparatus. This sketch shows provision for four simultaneous determinations. This obviously may be changed to a lesser or greater number. For the 110-volt circuit, just one-half of the resistance shown in the sketch is necessary. For the 500-volt circuit, just twice this resistance must be used. The resistance boxes and rheostat, if not at hand, may be made if it is not desirable to purchase them. "Nichrome" wire for the resistance; fiber board for the rheostat and selective switch; the contact pieces may be made of large, heavy, copper rivets; the contact arms of spring bronze. The rivets should be spaced so that the contact arms in their travel always touch one or two contact points. This obviates arcing. There should be, for the 220-volt circuit, about 400 ft. of No. 18 "Nichrome" wire for the rheostat, and 70 ft. of the same kind of wire for forming the coil from which the potential drops are taken by means of the selective switch.

There should be twenty-four contact pieces on the rheostat and ten contact pieces on the selective switch,



Semi-Diagrammatic Plan of Electrolytic Apparatus in Brier Hill Steel Co. Laboratory

1 Rheostat (About 6.5 Amperes, 250 Volts, 170 Ohms)
2 Selective Switch (10 Points)
3,4,5 Resistance Boxes (24 Grids each, .38 Ohms Resistance per Grid.)
6 Double Pole Switch in 220 Volt Circuit
7 & 8 Reversing Switches
9 220 Volt Motor (Fan Motor)
10 Ammeter (0 to 30 in .5 Amps.)
11 Voltmeter (0 to 30 in .5 Amps.)
A, B, C, D, Classen's Platinum Dishes for Electrolysis
A', B', C', D', Platinum Gauze Electrodes made to Rotate
A'', B'', C'', D'', Knife-Blade Switches, Double Throw for Passing Current either Through or by Ammeter and Voltmeter
12 Switch on Motor
13 Switch to Cut out Voltmeter

the leads from the rheostat being equally spaced along the 400 ft. of wire and in series with it. The leads from the 70-ft. coil to the selective switch are best adjusted by having the voltmeter and ammeter in circuit along with a pair of electrodes immersed in acidulated water. The current adjustment demanded by the class of work most handled may be easily and quickly obtained by increasing or decreasing the amount of resistance between successive shunts. The frames or boxes upon which the coils are to be wound are best made of "Transite" board. This may be worked with wood-cutting tools, and is resistant to heat as well as being a good non-conductor. The leads from the resistance coils to the rheostat and selective switch are of No. 12 well insulated copper wire.

The writer has used the outfit as sketched for the following determinations: Copper, tin, antimony (separation of tin and antimony), bismuth, nickel, manganese, iron, zinc and lead. The determination of lead in spelter was especially helpful, inasmuch as a great many determinations were required which, by the familiar

lead sulphate method, were very tedious and not nearly so accurate as the electrolytic method. To make a lead determination on spelter requires 30 min., the lead peroxide resulting from the electrolysis being ignited gently and weighed as the red oxide.

With some additional wiring and a small change in the selective switch, the apparatus may be arranged so that two or more unlike determinations may be handled at the same time; that is, a determination requiring say 5 amp. at 5 volts may be carried out with a simultaneous determination requiring 2 amp at 3 volts, etc. This is accomplished by using one pair of switch arms at the selective switch for each electrolytic place required. Each pair of electrodes must have, of course, its own pair of wires corresponding to their respective switch arms. It will be readily understood that by simply setting these switch arms so as to "bite" off the requisite resistances the voltages and amperages desired may be secured. However, this is a modification that is only desirable for quite variable work.

To conclude, the writer wishes to strongly emphasize the value and importance of a broader application of electrolytic work in the iron and steel laboratory, and hopes that the foregoing description will be of help to others desiring to test out such methods.

Acknowledgment of helpful suggestions and criticisms is tendered Mr. H. E. Moyer, chief chemist for the Brier Hill Steel Company, and to Mr. Samuel Farrell of the same corporation.

EDMUND J. KAUFFMAN.

Brier Hill Steel Co., Youngstown, Ohio.

Platinum Boats for Carbon Determination by the Direct Combustion Method

To the Editor of Metallurgical & Chemical Engineering:

SIR:—There has been a great deal written in the past few years in regard to the direct determination of carbon in iron and steel. Many methods have been described for its estimation, and while they are all practically the same in principle, many different suggestions are made as to the best materials to be used for constructing a furnace and for boats in which the small drillings are carried. Various materials have been mentioned for this purpose such as porcelain, fused silica, alundum, vitrified clay and nickel, but rarely, if ever, is platinum mentioned, perhaps on account of it being so expensive.

There appeared in this magazine for June (page 347) an article describing a method for preparing boats made of 22-gage sheet nickel; each boat to cost a trifle less than 5 cents, and good for at least forty combustions. On this basis let us make a comparison between nickel and platinum.

The writer has used the same platinum boat for five years and five months, doing an average of fifteen combustions each day, twenty-six days each month, or in other words the boat has been used for 25,350 combustions to date. The boat weighed 19.6 grams when purchased and it weighs at the present time 19.1 grams, so that there was a loss of 0.53 gram. It was purchased when new for $1.13 per gram, therefore the loss in platinum has cost $0.60. The boat is in fairly good condition at the present time, and is good for many more determinations. At the present price of platinum it could be sold for more money than it cost.

At forty combustions for each boat it would have required 634 nickel boats to complete the same amount of work done by this one platinum boat, and at 5 cents each the nickel boats would have cost $31.70, besides the trouble and expense necessary in preparing them from the sheet metal.

Nickel boats are more expensive than platinum, and they are also objectional from the fact that they readily take up oxygen at high temperatures, causing a continual formation of the black oxide which peels off in the form of small scales. This, of course, is an annoyance to the operator. A platinum boat is always ready for use and it is not necessary to scour it with cleaning compounds or treat it with strong acids to keep it clean. The only attention necessary is to keep it in shape as a boat, and this will not be found difficult if a suitable form is kept on hand for this purpose.

Great care should be exercised in regard to the flow of oxygen passing through the combustion tube, as this is an essential factor in prolonging the life of a platinum boat. With a furnace temperature of 1900 deg. Fahr., and a rapid flow of oxygen the temperature at which the reaction actually takes place will probably reach 2500 deg. Fahr., and at this temperature the drillings will run together like so much mercury and fuse with the boat, indeed sometimes they will bubble high above the boat and fuse with the combustion tube. Many times this has occurred to the above-mentioned boat and it has been found best to cool the furnace. When the slag becomes brittle it can be easily broken from the tube and the boat removed. When a platinum boat is removed from the furnace under these conditions it will not resemble its original shape by any means. In fact, it is a fused mass of platinum and slag. However, with an instrument for crushing the slag, such as a pair of pliers and a steel form, the slag can be removed and the boat hammered into shape in a few minutes. The best results are obtained when the oxygen is so regulated that the drillings just fuse together, but not to the extent that they cannot be recognized as drillings. When the reaction takes place too rapidly, the iron is partly volatilized and if barium hydroxide is used the precipitate will be found contaminated with the reddish brown oxide of iron. The results will invariably be low. Probably some of the carbon escapes through the absorption apparatus as carbon monoxide.

White silica sand is used freely in the boat, since it costs practically nothing. The sand is heated to 2300 deg. Fahr., for some time before using, to free it of any small amount of carbon. This sand being white offers a good background for the drillings and is very desirable for this work.

What has been said in regard to the use of platinum boats is equally true in regard to the use of platinum as a heating element for the combustion tube. The writer has used the same furnace every day for eighteen months, while on the other hand a furnace constructed in the same manner, but using nichrome for the heating element, will not average three months' use, and at the end of this time it is necessary to renew the nichrome, while with platinum the same piece can be used several times.

H. F. SIEVER.

NEW BEDFORD, MASS.

Newspaper Chemistry of Platinum

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The startling information contained in the following story, taken from the *Dowajiac Daily News*, is a beautiful example of "journalistic chemistry" and should be the means of furnishing some amusement to your readers:

"There is some valuable land down in Jefferson township. Recently a property owner on the line of the Mud Lake Extension drain sent to the State department at Lansing a sample of the excavation made when the drain was dug, and among other things the chemist found was platinum at the rate of 6 lb. per cubic foot of the formation.

"His primary object was to see how much lime the marl contained, and he was informed that the marl was over 90 per cent pure lime.

"Years ago, when platinum was worth $12 per lb., his land was a gold mine, although in those days cost of extracting this metal was correspondingly great, perhaps. With the facilities now in use for extracting, platinum has grown to be valued less than $1 per lb. Even at that price the land is pretty valuable."

Dowagiac, Mich. J. C. A.

The Western Metallurgical Field

Parcel Post Ruling to Affect Shipment of Concentrates

Since the parcel post was established, one of the most difficult problems confronting the Post Office Department has been the handling of tons of concentrates that have been shipped from isolated districts to smelting centers. Concentrates properly come within the classification of parcel post matter, and when put up in 50-lb. sacks have been entitled to the established rates. This method of shipment has been a convenience to producers operating at a distance from reduction works, and many of them have taken advantage of this method of transportation.

The Post Office Department has discovered, however, that the business is not profitable because the length of rural mail routes is frequently much greater than the parcel post zone radius as the crow flies. This often necessitates carrying concentrates a distance equivalent to two or three zone radii, and as a consequence the business is conducted at a loss. Hence a ruling has been made that where the mail route is 300 miles or more between points of shipment and delivery the regular first and second zone rates shall not apply, even though the route lies within those zones on the map, but that third zone rates shall be charged. This means, for example, that where the second-zone rate of 5 cents for the first pound and 1 cent for each additional pound has previously been in effect on some 300-mile routes, the third-zone rate of 6 cents for the first pound and 2 cents for each additional pound shall apply. This will increase the ordinary second-zone rate from $1.08 to $2.08 per 100 lb., or at the rate of $20 per ton. This is an increase that will force many operators to discontinue shipping by parcel post; the rural mail carrier may again use a two-wheel cart instead of a motor truck, and the government will be relieved from an unprofitable business.

Anaconda to Enter Zinc Field

Certain activities on the part of the Anaconda Copper Mining Company point to the possibility of that company becoming a factor in the zinc industry. Anaconda engineers have recently been examining property in the Neihart district, one of the zinc-mining districts of Montana, where silver-zinc ore has been produced, though with unsatisfactory results. In the Butte district also the Anaconda is reported to be investigating zinc properties, such as the Emma and Lexington, and it is reported that when the sale of the Alice is finally consummated the purchaser will be the Anaconda company.

With the acquisition of zinc properties, it is likely that Anaconda has also developed metallurgical methods to treat the ore, and some credence may be placed in the report that the company's metallurgists have been experimenting along the line of electrolysis. Electrolytic zinc has been in the public eye for some time, and has received quite as much attention as did electrolytic copper. The development of an economic hydrometallurgical method for zinc, with electrolysis as the final step, would be a tremendous advance in zinc metallurgy; in fact, it would prove revolutionary in an industry in which the basic methods have never undergone any material change. Were the report credited to any less energetic and capable an organization than Anaconda, it might not be worth a passing consideration, but the progressive character of Anaconda's program in copper metallurgy leads one to feel that new developments in zinc-ore treatment might easily emanate from that source.

American Graphite Manufactures

In view of an interest recently manifested in the domestic production of graphite and its manufactured articles, we give the following information: The production of natural graphite in the United States in 1913 was 4775 short tons. Imports amounted to 28,879 short tons. The principal reasons for the disparity in domestic production and imports are to be found in the superiority of the Ceylon product and its cheap production, and the difficulty in milling the domestic ores. Deposits in the United States are mainly flake graphite in schist. The separation is difficult, especially when the rock contains mica, which is frequently a constituent. Failure has attended so many undertakings in the production of graphite from domestic deposits that the work is in the hands of a few concerns which also manufacture the output into marketable forms.

Domestic graphite is not suitable for the manufacture of pencils, as it lacks that unctuous quality so necessary in producing an even grade of "lead." Crucibles, paints, lubricants and stove polishes are the manufactured forms to which the American graphite is most suited. The Santa Maria graphite mines in Sonora, Mexico, produce amorphous graphite containing 86 per cent graphitic carbon, which is shipped to Saginaw, Mich., and there prepared for use by the Raymond system of pulverizing and air-separation. American-made pencils, of quality said to be equal to that of German and Austrian manufacture, are now produced almost wholly from this Mexican graphite.

Silver and Base-Metal Prices

The steady decline in the price of silver is a matter of grave concern to producers of the white metal, particularly in view of the enhanced value of zinc, aluminium and potassium cyanide which are used in its production. Quicksilver also is used in large quantity at Cobalt, but as it is subject to but little loss in the process of amalgamation, its high price is not a matter of so much importance. In fact, the Buffalo company probably discovered a neat asset in the 41,850 lb. of mercury recovered from residues during the year ended April 30, 1915.

Tonopah and Cobalt are the great silver producing districts on the North American continent, and companies operating there have been forced to witness a steady decline in the value of their product while the cost of supplies has risen. The effect has been to cause operators to store silver bullion in New York and San Francisco until a more favorable market appears. But even this expedient has its unfavorable aspect, for by the time the market recovers to a normal condition the large stores of silver available will tend to hold prices down. Most of the companies concerned are well financed and can await a favorable time to dispose of their product, but smaller companies that have to realize promptly on their output are operating under most unfavorable conditions.

Potash in Utah

The Mineral Products Company, which is developing deposits of alunite at Marysvale, Utah, expects to have its milling plant in operation in September. Accord-

ing to General Manager James A. Lane, no attempt will be made at present to recover aluminium, which is a constituent of alunite, and potash only will be produced. The company has been constructing a tramway and mill, and will begin operations under favorable market conditions.

Flotation at Park City

We have recently commented on the fact that the older mining districts offer fertile fields for the application of the flotation process, particularly where concentrating mills of the customary type have been the only treatment plants in operation. A case in point is the Park City district, Utah, where gravity concentration of lead-zinc ores has long been practised. The Daly-Julge mill is to add the Callow pneumatic flotation process to its present equipment, and thereby effect a saving of fine mineral that has hitherto gone to waste. Another project in the same district is the construction of a mill to re-treat the old tailings of the Grasselli company's dry concentrating mill. The flotation process will be used here also, in addition to the usual methods of wet concentration. At Atkinson, near Park City, a new 250-ton mill has been erected for the treatment of old tailings, flotation playing a prominent part of the process.

Company Reports

Utah Copper Company's report for the second quarter of 1915 shows a production of 40,799,825 lb. of copper from 2,215,159 tons of ore containing 1.42 per cent copper. The extraction was 64.85 per cent, being below normal due to the presence of considerable carbonate mineral in the ore, and to the extra large tonnage handled. The tonnage treated was the largest for any quarter in the history of the company. The cost of copper, without crediting miscellaneous earnings, was 7.49 cents per pound. With other earnings credited, the cost is 6.57 cents. Total net profit from all operations was $4,412,299, from which a dividend was paid amounting to $1,624,490. Of the total quantity of ore milled, the Magna plant handled 59 per cent and the Arthur plant 41 per cent.

Ray Consolidated Copper Co. treated 679,004 tons of ore during the second quarter of 1915, producing 14,524,380 lb. copper. The average grade of the ore was 1.677 per cent copper. Milling costs totaled 44.53 cents per ton, as compared with 48.95 cents for the previous quarter. Coarse crushing cost 3.256 cents per ton. The average cost of copper, after allowing for smaller losses and applying dividends from the Ray & Gila Valley Railroad, was 9.122 cents per pound. Crediting miscellaneous income, the average cost would be 9.057 cents. The net operating profit was $1,367,736; dividend amounted to $547,035. Production for the quarter averaged nearly 1000 tons below what it should have been under normal conditions. Delay in resuming operations on a full tonnage basis, coupled with labor difficulties in June combined to cause a deficiency in production.

Chino Copper Company produced 18,455,502 pounds of copper during the second quarter of 1915. The mill treated 592,200 tons of ore containing an average of 2.38 per cent copper. The average daily tonnage was the highest in the history of the mill, reaching up to 7317 tons per day in June. Extraction was 65.34 per cent, as compared with 66.12 per cent in the previous quarter. The concentrates contained 22.11 per cent copper, as against 27.41 per cent for the first quarter. The ratio of concentration was 14.19:1. Cost of copper, allowing for smelter deductions and crediting miscellaneous income, was 6.10 cents per pound. Net profit from milling operations, $1,937,951; dividends paid, $652,455.

Nevada Consolidated Copper Company produced during the second quarter of the calendar year 15,106,920 lb. of copper, the June production being 5,124,480 lb. Ore milled amounted to 849,155 of Nevada Consolidated ore averaging 1.40 per cent copper. In addition to this there was also milled 17,541 tons of Giroux Consolidated ore. The cost of copper, after crediting miscellaneous income, was 8.93 cents per pound. Earnings for the quarter amounted to $1,364,094, from which dividends were paid amounting to $749,796.

The Non-Ferrous Metal Market

Since our last report the non-ferrous metal market has been comparatively quiet and without particular feature. Prices have steadily declined and business has been only moderate. While sales have been mainly for the domestic market, there is evidence that export business will again increase and it is not felt that the reaction will be marked or of long duration.

Copper.—Export business has suffered somewhat from the sale of Australian and Japanese copper in the European market, but resumption of foreign sales has already begun. Domestic business has been small and at reduced prices. The latest available quotations for electrolytic are 17.60@17.80 cents, New York.

Lead.—Due to a sharp reduction in price by the American Smelting & Refining Company this market has lost its optimistic tone that it showed in July. Competitors have still further reduced the price, so that lead is now quoted at about 5 cents, New York, and 4.90@5 cents, St. Louis.

Tin.—This market has been without special feature. Prices have shown a declining tendency, and the metal is quoted at 35½ cents, New York.

Spelter.—The metal has been consistently weaker for several weeks and the volume of business is small. There seems to be an ample supply for both immediate and future demands. Some metal has been offered for resale by buyers who overbought their requirements. The St. Louis quotation is about 14.50@15 cents.

Other Metals.—Aluminum continues at a fairly high level with fair demand. No. 1 ingots at New York are quoted at 31@33 cents per pound. Prices for antimony are largely nominal, ordinary brands bringing from 35 to 37½ cents, and special brands 48 to 50 cents. Business in quicksilver is only fair, with prices at $92@94, New York, for flasks of 75 lb. The San Francisco market is quiet with prices about the same as at New York.

The Iron and Steel Market

August has shown a further improvement in the steel situation. Although practically 100 per cent of the open-hearth capacity and about 90 per cent of the Bessemer steel-making capacity has been engaged, steel has been described as scarce and prices demanded for billets and sheet bars support such a view. Mill deliveries have lengthened out so that against new specifications filed for plates and shapes the large mills do not promise shipment in less than four to six weeks, while in the case of bars deliveries are still slower. Steel prices have been advancing.

On the surface at least the steel market presents an appearance of great strength, and in most quarters the prediction is made that the trade is definitely promised a long period of full prosperity. When the market situation is analyzed, however, it becomes clear that its strength is due chiefly to export demand, and that mainly for war purposes. This demand has had both a direct and an indirect effect in filling the steel mills

with business. Indirectly it has affected domestic buying by stimulating the price advancing tendency and by causing buyers to fear they may not be able to secure desired deliveries. In the last report it was noted that when mill deliveries begin to fall behind buyers are moved to increase their stocks, and while it was then noted that such an extra demand was being experienced it may be stated that the buying during August was still more of that character.

The government figures for June show exports of iron and steel totalling 355,829 gross tons, against 263,649 tons in May, and an average of 137,000 tons a month during the first seven months of 1914 preceding the outbreak of the war. Excluding pig iron, scrap, castings, etc., the June exports represented about 320,000 gross tons of rolled steel. Indirect exports, including machinery, arms, ammunition, motor cars, etc., may have involved 80,000 tons in addition, making 400,000 tons for the month. The country's capacity, measured as rolled steel is probably about 2,400,000 gross tons monthly, with average weather conditions and after all departments have been in operation long enough to have reached normal efficiency. The June production was probably in the neighborhood of 1,800,000 tons, so that steel export, direct and indirect, appears to have represented about 22 per cent of the output. Exports have been steadily increasing since June in various directions. Large shipments of rails are to be made to Russia, purchases to date having amounted to 250,000 or 300,000 tons, while a large number of cars and locomotives has been bought by France and Russia, and there have been increases in many items that figured in the June exports. It is quite possible that in September direct and indirect exports may represent as much as 600,000 tons of rolled steel, but as moderate weather arrives and the mills through continued operation reach their proper gait it will be possible to produce more steel, probably the 2,400,000 tons per month already estimated, so that allowing for a gain of one-half in exports over what is suggested by the latest government statistics, the exports would represent only 25 per cent of capacity, indicating that in some quarters the importance of the present export trade, from a tonnage standpoint, is being over-estimated. There is little danger, however, of the influence upon the market being overrated, however, because, as indicated, the export business has had an important sentimental influence in helping the advance in prices and encouraging buyers to specify freely on their contracts.

Without admitting these influences it would be impossible to find in industrial conditions in the United States occasion for the steel industry to operate at its capacity. There is no important branch of domestic consumption in which business is active or in which the tonnage actually consumed is at previous record rates, whereas the steel industry has a larger capacity than ever. A few illustrations may be cited. The railroads have bought rails scarcely more freely this year than in 1914, but the production of rails last year was less than 2,000,000 tons, or only one-half the record production, made so long ago as in 1906. The last time the steel industry reached a rate of full employment was at the middle of 1912, and in the eight months preceding there has been 135,000 freight cars ordered. Freight car buying this time has been active only in the three months, May, June and July, orders in those months aggregating about 55,000 cars. Prior to May there was no buying to speak of, and there has been none of any consequence in August. The reports of the Bridge Builders' and Structural Society, covering fabricated steel contracts let throughout the country, show an average in lettings during the first six months of this year representing only 54 per cent of the capacity, while in the single month of July the contracts amounted to 86 per cent. Oil development is practically at a standstill, and has been for a year, while in a good year the "oil country goods" branch of the pipe industry involves nearly a million tons. In the sheet branch there is nearly normal demand for blue annealed and black sheets, but not one-third the normal demand for galvanized sheets.

Admittedly the steel trade finds itself in a prosperous condition, but obviously the condition is not referable to anything like normal full domestic consumptive demand, while even the export demand does not appear to fill the gap. As the country grows more prosperous the domestic consumption may, and probably will, increase. Perhaps the final test will come with October, normally a month of very large outputs, as the plant facilities work well. If the market finds itself strong at the end of October, with firm prices and no surplus of steel, the industry may be regarded as assured a period of prosperity of considerable length.

Pig Iron

The advance in pig iron prices, which became perceptible in the fore part of July and reached more important proportions in the second half, became very marked in August. Averaging all important descriptions of pig iron, the July advance amounted to about 35 cents a ton and the August advance to about 90 cents, a total of $1.25 for the two months. Prior to July the pig iron market had merely shown minor fluctuations.

The advance in pig iron has not rested upon as large a volume of sales as has usually occurred in the case of price advances of similar extent. The conditions were exceptional. There is a much wider range in pig iron costs at the merchant furnaces than there is at the furnaces of the steel works, one important factor being that some of the merchant furnaces have ore mines of their own while others must pay the market price, and an interest having ore mines and blast furnaces may be content to show an apparent loss to the blast furnace operation if the ore is charged to it at the market price. Last winter the furnaces in operation were confined almost entirely to those with ore supplies of their own, and even they were operating at no considerable profit. Pig iron prices remained low for so long that the furnaces were tempted to sell pig iron far ahead. At the beginning of July the furnaces found themselves almost entirely sold up for the second half of the year, while consumers were equally well covered, on the basis of the rate at which they had been consuming iron. A slight increase in their requirements caused additional buying, while the furnace position was that the operating furnaces were already well sold up and the idle furnaces were unable to sell and enter the producing ranks, their costs being well above the market. Accordingly, prices rose rather sharply on relatively light buying. To justify blowing in, a furnace must be able first to sell a considerable tonnage of pig iron, assuming prices to be satisfactory, and the market has hardly been broad enough to permit this. The market stands quotable as follows: No. 2 foundry, delivered Philadelphia, $15 to $15.25; f.o.b. furnace, Buffalo, $14 to $14.50; delivered Cleveland, $14.50; f.o.b. furnace, Chicago, $13.50 to $14; f.o.b. Birmingham, $11 to $11.50; at valley furnaces, 95 cents higher delivered Pittsburgh: No. 2 foundry, $14.25 to $14.50; gray forge, $14 to $14.25; malleable, $14.25 to $14.50; basic, $14.25 to $14.50; Bessemer, $15.50. These quotations are for relatively early delivery, and quotations for the first quarter or half of next year are usually on a higher basis.

Steel

The large consumers of billets and sheet bars are well covered by long term contracts. On some of these prices are adjusted monthly or quarterly, and have been increasing slightly. On a few contracts, particularly for sheet bars with tin plate mills, there is usually one price for the entire calendar year. The demand that passes through the open market is thus very small compared with the tonnage that changes hands, and in periods of relative scarcity the market is sensitive and not very clearly defined. Some of the producers are refusing to quote, having but small tonnages to spare, after filling contracts, and feeling safe in holding the steel for still higher prices. The middle interests have some steel but are naturally reserved in selling. As nearly as can be quoted the market stands at about $23.50 to $24 for billets and $24 to $24.50 for sheet bars at maker's mill. Bessemer steel might possibly be had for less while it might be difficult to buy open-hearth at these figures. Rods are $26 to $27, Pittsburgh.

Finished Steel

Finished steel products have, generally speaking, shown an advancing tendency. In bars, plates and shapes the new buying has been light, but specifications against contracts have been so heavy that the mills have felt strong enough to advance asking prices. On Aug. 16 the steel corporation subsidiaries announced an advance of $1 a ton in bars, plates and shapes, to 1.35c.; Pittsburgh and the other large interests are working up to this basis. There remain small plate mills willing to sell plates at 1.25c.

Current quotations, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.25c. to 1.35c.

Shapes, 1.30c. to 1.35c.

Steel bars and bands, 1.30c. to 1.35c., base; hoops, 1.35c. to 1.40c.

Iron bars, 1.25c., Pittsburgh; 1.40c. to 1.45c., Philadelphia; 1.25c. Chicago.

Sheets, blue annealed, 10-gage, 1.40c.; black, 28-gage, 1.85c. to 1.90c.; galvanized, 28-gage, 3.60c. to 3.75c.; painted corrugated, 2.00c. to 2.05c.; galvanized corrugated, 3.65c. to 3.80c.

Tin plate, $3.10 to $3.20 for 100-lb. coke.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 63½ per cent off list.

Steel boiler tubes (less than carloads), 72 per cent off list.

Structural rivets, 1.50c.; boiler rivets, 1.60c.

Railroad spikes, 1.45c., Pittsburgh; 1.60c., Chicago.

Imports of Potash Salts.—The following table from **Commerce Reports** shows the quantity and value of imports of potash salts into the United States during the month of May and for the five months ending May, 1914, and 1915. The items are grouped to show the salts used chiefly as fertilizers and other potash salts. The unit of weight is the long ton.

Articles	May				Five Months Ending May			
	1914		1915		1914		1915	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Fertilizer salts:								
Kainit	11,960	$59,641	.....	.....	239,362	$1,115,151	3,786	$31,553
Manure salts	19,047	203,632	197	$7,639	81,669	895,739	12,456	179,328
Sulphate of potash	2,162	94,788	33	2,204	21,313	907,635	8,806	405,631
Muriate of potash	17,952	619,397	28	3,845	105,759	3,606,445	56,135	2,336,098
Other potash salts:	Pounds		Pounds		Pounds		Pounds	
Carbonate of potash	1,621,787	48,548	769,047	24,947	9,867,075	282,758	8,396,034	261,234
Hydrate of potash	811,313	28,442	141,500	6,389	3,462,638	128,613	2,016,942	97,956
Nitrate of potash	475,724	15,170	.....	.....	1,079,045	35,599	6,855	400
Cyanide of potash	1,236	16	.....	.....	275,977	37,362	828,527	124,934
Other potash salts	512,383	44,519	67,203	7,698	2,704,391	241,075	2,064,260	202,570

Transvaal Gold Production.—The number of mines reporting to the Transvaal Chamber of Mines in April, 1915, was sixty-three. The total quantity of ore milled during that period was 2,341,595 tons. There were 9907 stamps in operation, with an average duty of 9.35 tons per 24 hr. Tube-mills in commission numbered 316. The yield for the month was 744,080 fine ounces gold, or 6.22 dwt. per ton.

Repairing Coke-Ovens by the Cement-Gun Process.—The Cement-Gun Company, Inc., 30 Church Street, New York City, describes in its Bulletin 101 the application of the cement-gun process for permanently repairing coke ovens. This method is interesting as it permits the repairs to be made while the oven is in service, thus doing away with the troublesome effects of cooling and reheating. The "gun process" is the same in principle as has proved so successful in other fields of cement repair work in recent years. The material used in the gun is the usual silica cement which is used in joints in the construction of the walls. This consists of siliceous material such as ground silica rock and ground batts in varying proportions from 100 per cent of the one to 100 per cent of the other mixed with 15 per cent to 20 per cent of fireclay. The finished cement generally running from 85 to 80 per cent silica. The material being deposited in the form of a spray and under high pressure penetrates deeply into the cracks, thus insuring a perfect seal.

Oil Pipe Line.—The first four sections, comprising about 47 miles of the oil pipe line for the Valley Pipe Line Company, a subsidiary of the Shell Royal Dutch Company, which was designed and is being built by Sanderson & Porter, was placed in successful operation on May 15th. This line is 170 miles long, extends from the Coalinga oil fields to a tidewater terminal near Martinez in San Francisco Bay, and will have a carrying capacity of 25,000 barrels per day. In order to comply with the wishes of the Shell Company for prompt completion, the constructing engineers, Messrs. Sanderson & Porter, have pushed this work through in what is believed to be record time. The storage capacity of the pumping stations now in operation on this first section of the line amounts to 225,000 barrels, which is thus made immediately available for the storage of surplus production.

New Zinc Smelting Plants.—Within the past few weeks a number of old and abandoned zinc smelting plants have been put into commission, and new furnaces have been added to existing plants. The U. S. Steel Corporation is making good progress on its new zinc and acid plant at Donora, Pa. The U. S. Smelting, Refining & Mining Co. has purchased old plants at Iola, La Harpe and Altoona, Kan., giving the company an aggregate smelting capacity of 8000 retorts. The Grasselli Chemical Co. is adding two blocks of furnaces at Meadowbrook. Two blocks are being built in connection with the east plant at Pittsburgh, Kan., two at the Sand Springs works, one at Chanute and one at Bruce. An old plant at Nevada, Mo., is to be put in operation this month.

Los Angeles Meeting of the American Institute of Chemical Engineers

The meeting held at Los Angeles from Aug. 16 to 18 by the American Institute of Chemical Engineers is the prelude to a long series of meetings to be held this fall on the Pacific Coast by the national chemical societies. It is to be followed shortly by another meeting of the same institute at San Francisco.

The Eastern members and friends of the institute—some thirty in number—had come to Los Angeles in several parties over the Santa Fé road. The main and official party was personally conducted by the secretary of the institute, Dr. J. C. Olsen, since the president of the institute, Dr. Rosengarten, was unfortunately prevented from participating in the trip on account of sickness in his family. Stops were made on the trip at Colorado Springs for excursions to Pike's Peak and Cripple Creek, and at the Grand Canyon in Arizona, while the exposition at San Diego, so delightfully characteristic of Southern Californian life and achievements, was enjoyed for a number of days.

The institute was entertained at Los Angeles with truly unbounded Californian hospitality by a local committee of the institute, consisting of Messrs. Edgar Baruch and D. B. W. Alexander, in conjunction with the Southern California Section of the American Chemical Society, of which Mr. Baruch and Mr. Henry L. Payne—both real live wires—are chairman and secretary respectively. For the many automobile trips which had been arranged for the entertainment of the visitors, cars were provided by Messrs. E. Baruch, N. M. Hill, R. B. Peters, H. J. Reese, M. P. Waite, Mark Walker and F. C. Winter. Among many others who did a great deal for the entertainment of the visitors, Messrs. W. L. Jordan, H. L. Potter, W. Hirschkind, H. L. Keller, C. H. McCharles, M. P. Spencer, and Mr. Thatcher of the Kieselguhr company should be specially mentioned. With so many active hosts it goes without saying that the visitors were almost overwhelmed with entertainment.

On Monday, Aug. 16, a 120-mile automobile trip was made; first to Redondo Beach, where the oil-fired power station of the Pacific Light & Power Company was inspected; it contains reciprocating sets of 15,000 kw. and turbine sets of 24,000 kw.; the cleanliness of an oil-fired boiler house was duly admired. The automobiles then proceeded to Long Beach; on the way the large-scale precipitation of salt from sea water with the aid of the sun's heat was seen. Lunch was taken at the Hotel Virginia in Long Beach.

In the afternoon the party proceeded to Huntington Beach, where the beet sugar factory was visited and the different chemical engineering processes were explained by the superintendent, Mr. Joseph Varra, and the chief chemist, Mr. A. C. Horn. The return trip to Los Angeles was made over Santa Ana and Orange through extensive walnut and fruit orchards.

The same evening a trip was made to Alhambra, where the mission play, concerned with early Southern California history, was seen. The whole of Tuesday was devoted to a trip to Santa Catalina Islands, while on Wednesday afternoon an automobile trip was made to Pasadena, and on Wednesday morning an automobile trip to the Fullerton oil fields, where the process of "squeezing" gasoline out of natural gas was shown. The technical details were fully explained by Mr. A. Yost, superintendent of the Brea Canyon Oil Company, and Mr. W. A. Culp, superintendent of the Pacific Gasoline Company. The informal lunch of watermelons and figs and the spectacle of a burning snowball (of frozen gasoline) will never be forgotten.

On the evening of Wednesday a joint meeting of the American Institute of Chemical Engineers and of the Southern California Section of the American Chemical Society was held at the University Club, and was preceded by an informal dinner. The attendance was about seventy. The occasion was graced by the presence of many ladies. Mr. Baruch presided. Introductory speeches were made by Dr. J. C. Olsen and Prof. J. M. Stillman of Leland Stanford University, vice-president of the American Institute of Chemical Engineers, who had specially come from Palo Alto to Los Angeles to welcome the institute to California.

Two very interesting papers were presented and elicited some extended discussion.

The first paper, by Mr. W. C. Hanna of the California Portland Cement Company at Riverside described the Fleming dust collecting system which is successfully used at that plant for collecting any dust and preventing damage to the surrounding orange groves. Briefly, the installation consists of normal rotary kilns using dry process and oil for fuel. The draft for the kilns and dryers is produced by fans sucking at the ends of separate flues. Instead of discharging the gases into the atmosphere, the same exhauster fan blows the dust and fumes into a large "dry dust settling chamber," where the velocity of the gases is reduced about 90 to 95 per cent, resulting in a large amount of dust being deposited.

The extremely fine dust which does not settle, and the gases, then go to the "wet washing chambers," where the gases are forced up and down several times while following a serpentine course through a system of seven baffle chambers, and the last of the original so-called cement dust is captured by sprays of water which are in each chamber.

These sprays of water also bring into solution much of the gases, lime and alkalies. In connection with both the dry and the wet chambers there are means provided for the removal of the captured dust to the cement kilns.

The second paper of the evening, by Dr. J. C. Olsen of New York City, described "a new electrolytic method of sewage disposal," in operation at Elmhurst, in New York City, for more than a year. The C. P. Landreth process is used.

The principal novel features, which distinguish it from other electrolytic processes for sewage disposal, are, first, that lime is used together with electrolytic treatment, and, second, that a much smaller quantity of electricity per gallon is used than in other processes. A very thorough system of agitation is also employed.

We reserve publication in full of these two very interesting papers for a future issue.

On Thursday, Aug. 19, the party left Los Angeles to proceed to San Francisco. But several stops were made on the way. The main party left the train at Oxnard, to visit, under the guidance of Mr. H. E. Zitkowski, general chemist of the American Beet Sugar Company, the Oxnard sugar factory, which is the largest beet sugar factory in the world.

The ladies of the party, under the guidance of Prof. Edward Bartow, proceeded to Santa Barbara to enjoy the beauties of the "California Riviera."

The writer left the train at Surf, and was royally entertained by Mr. Krieger on a visit to the immense and unique high-grade kieselguhr deposits at Polnoc and to the extended mills which have grown up in the last three years to supply kieselguhr or celite in various forms to the most diversified industries—a new proof that the old creative California pioneer spirit is to-day as live as ever.

Roasting and Leaching Concentrator Slimes Tailings*

BY LAWRENCE ADDICKS

Through the courtesy of Dr. James Douglas I am permitted to give a summary of some of the results obtained in leaching slimes tailings in a series of experiments conducted under my direction at Douglas, Ariz., during the past year.

While the test run for which the data are given deals with a particular case, much of the work is general in its application and may therefore be of interest.

This work was done upon the ores of the Burro Mountain Copper Company. A description of the geology of the district will be found in the paper by R. E. Somers published in the May, 1915, *Bulletin* of the Institute.

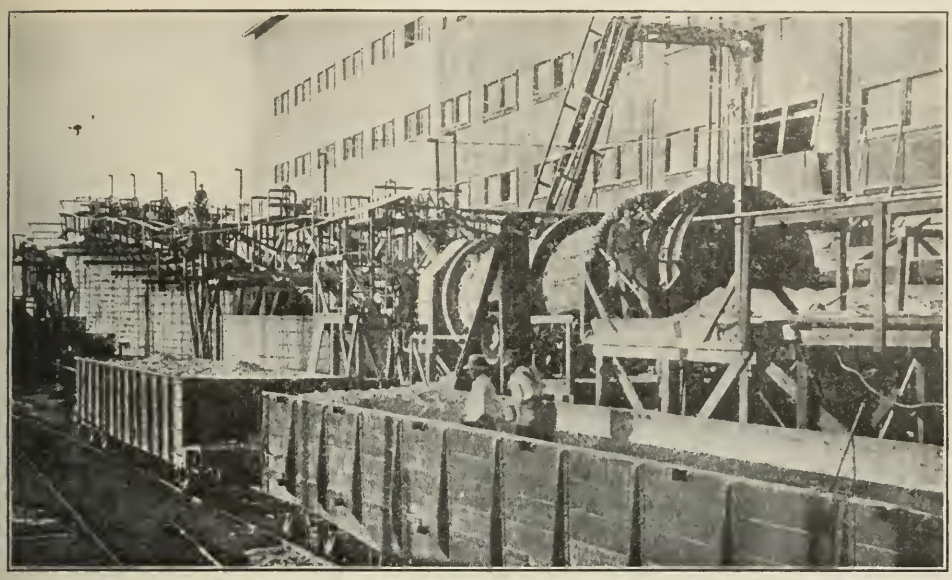


FIG. 1—GENERAL VIEW OF LEACHING PLANT

The mineral is pyrite and chalcocite very finely disseminated throughout the gangue and a characteristic of all the ores is the large amount of alumina present.

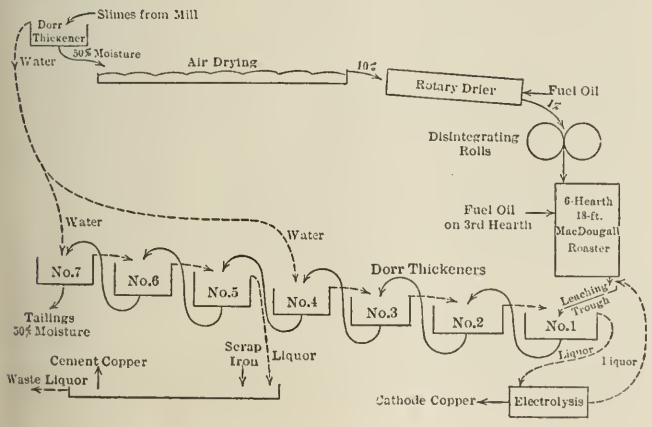


FIG. 2—FLOW-SHEET OF LEACHING PLANT

A representative analysis of the particular ore under consideration would be about as follows:

Cu, per cent	2.35	S, per cent	3.0
Ag, ounces per ton	0.05	CaO, per cent	0.5
Au	None	K_2O, per cent	4.0
Fe, per cent	1.5	SiO_2, per cent	70.0
Al_2O_3, per cent	13.0		

The leaching of the ore direct was early dismissed from consideration for the following reasons:

1. The ore would have to be quite finely crushed to liberate the mineral for leaching; concentrating after crushing would cost but a few cents a ton; and a higher total recovery would result from leaching tailings rather than ore.

2. Rough concentration would yield a suitable material for roasting to make sulphur dioxide or sulphuric acid in connection with the leaching scheme.

3. Such a program put the question of cost vs. recovery on a basis where flotation and discarding of tailings were directly comparable.

Concentrating experiments already available indicated that the tailings would consist of about 50 per cent of sands running about 0.3 per cent in copper, and therefore too low to justify retreatment, and 50 per cent of slimes running perhaps 1 per cent in copper, and it was on this latter material that the large-scale work was finally done.

At first flotation gave very unsatisfactory results, due primarily to the readiness with which the fine mineral particles became coated with a film of oxide upon exposure while concentrating, but later developments in this field overcame these difficulties and it became apparent just about the time the leaching plant was being started that the concentrator recovery was going to be so high that re-treatment of the tailings would not be justified. Nevertheless, for the sake of the data it was decided to carry through a representative run, the results of which are discussed below.

Fig. 1 is a view of the leaching plant, and the general scheme is shown in the flow sheet, Fig. 2. As the development of the electrolytic precipitation is really a subject apart from the leaching of the slimes, the results from this part of the work have been reserved for a separate paper. A part of the copper is shown recovered as cement in order to give a means of holding the iron and alumina in the liquor to be electrolyzed down to the desired point. A high ratio of washing can be used in the thickeners delivering to the cementation launder; in the remaining thickeners the ratio is governed by the evaporation loss, as there is no other outlet for liquor.

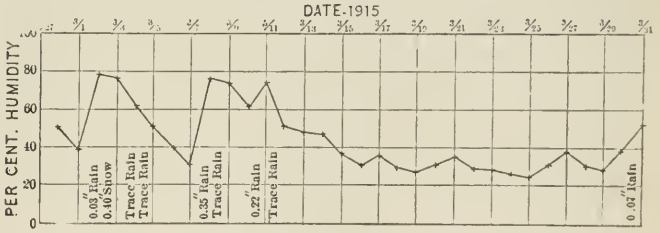


FIG. 3—MOISTURE IN AIR

The experiments will be taken up in detail under the headings of: (1) drying, (2) roasting, (3) leaching, and (4) washing.

Drying

As the slimes would be delivered from the concentrator in suspension as a thin pulp, it became necessary to consider carefully the question of drying.

*A paper to be presented at the San Francisco meeting of the American Institute of Mining Engineers, September, 1915.

Thickening experiments indicated that there was a critical degree of moisture of about 45 per cent, below which pumping the settled slimes resulted in further classification of the fine particles instead of delivering average pulp, so that thickening in a standard Dorr unit to 50 per cent of moisture was established as the first step.

As fuel is very expensive at the location in question and no waste heat can be counted on except that from the roaster gases, experiments were made with drying by exposure to the desert sun and winds. The heavy

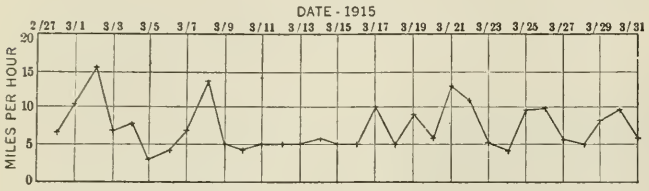


FIG. 4—WIND VELOCITY

pulp could well be poured into a shallow basin and the more or less dried slime reclaimed by some mechanical method for much less expense than an equivalent drying using artificial heat would cost. It was found that the pulp settled to about 30 per cent of moisture very readily when allowed to drain and that reasonable dry material could be obtained by a month's standing.

Figs. 3, 4, 5 and 6 give the measurements taken during the trial on three test beds, 10 ft. square, and respec-

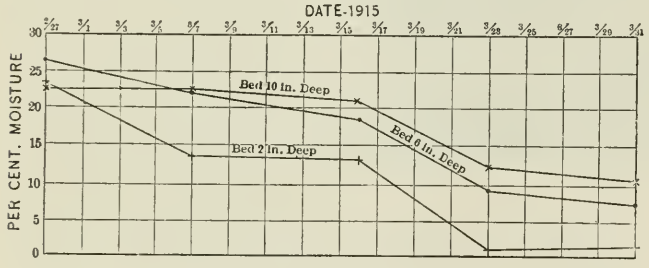


FIG. 5—MOISTURE IN SLIMES

tively 2, 6 and 10 in. deep, which were exposed to the atmosphere for about a month.

The climatic conditions are shown in Figs. 3, 4 and 6, and it will be noted that periods of both cold and wet weather were encountered during the first part of the run, much more favorable conditions following in the last two weeks. A bed only 2 in. deep would cost a good deal to reclaim, but the rate of drying, as shown in Fig. 5, was thought to indicate that a reasonably thick bed could be brought down to 10 per cent of moisture with-

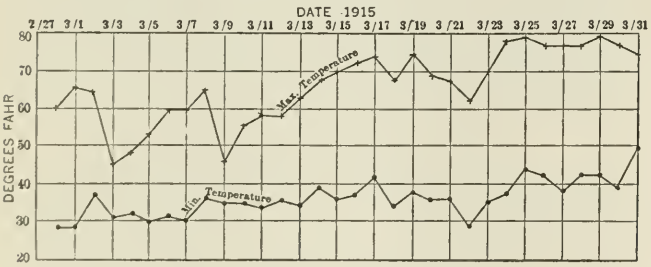


FIG. 6—TEMPERATURE OF AIR

out an excessive period of standing, and it seems probable that this will be the cheapest way to obtain this preliminary drying.

Up to this point the experiments were conducted on relatively small quantities of material, but starting with the following step—drying in the rotary kiln—large tonnages were handled. Instead of using atmospheric drying before feeding to the kiln, steam coils were buried in the cars of mushy slimes shipped to the experimental plant, bringing the moisture down to about 25 per cent, when it was shoveled directly to the drier.

This drier was one of the old Douglas roasters, 7 ft. in diameter and 31 ft. long. It was used as an ordinary unlined rotary kiln, with channel-iron spilling blades throughout the first two-thirds of its length, and cast-iron balls 3 in. in diameter feeding against a delivery screen made of sheet-iron plate with 1½-in. round holes. The idea was to dry and pulverize any caked nodules in the one apparatus. The outside was lagged with 1½-in. magnesia block, and heat was supplied by three oil burners at the delivery end. Two typical runs gave the following results:

Days run	23.0	12.0
Total tons dried	710.0	388.0
Tons per day	30.9	32.3
Per cent moisture entering	26.6	10.0
Per cent moisture leaving	1.1	2.0
Gallons fuel oil per day	404.0	154.0
Gallons fuel oil per ton dried	13.1	4.8

In general, it was concluded that about ½ gal. of fuel oil must be provided for each unit of moisture in the ore to be dried, so that 5 gal. would have to be charged against drying a 10 per cent product from the atmospheric drying beds, although this amount might be lowered in a properly designed drier. The capacity of the

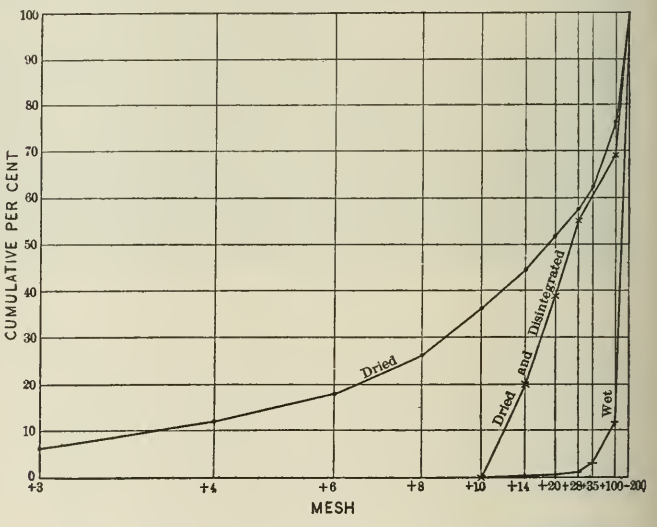


FIG. 7—CUMULATIVE SCREEN ANALYSIS OF SLIMES

drier was too low for the roaster used, and the pulverizing action of the iron balls inadequate, so the dried material was passed through a pair of disintegrating rolls, returning any oversize through a 10-mesh screen,

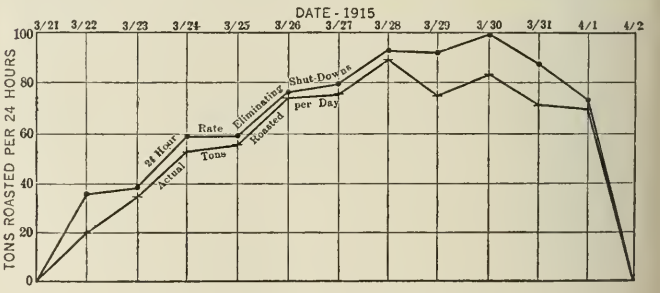


FIG. 8—TONS ORE TO ROASTER

and dried and disintegrated material was stored ahead of the roaster.

Fig. 7 shows cumulative screen analyses of the original wet slimes, the drier product, and the disintegrated material, made on the usual Tyler direct diagram. It must be remembered that the lumps formed in the kiln could be readily crushed between the thumb and forefinger, being merely caked clay. The danger was that

these lumps would be burned hard in the subsequent roasting.

The arrangement of the drier with skip feeding to roaster, and the row of Dorr thickeners can be readily seen in Fig. 1.

Roasting

The roasting was carried out in a standard six-hearth, 18-ft. MacDougall furnace with water-cooled arms, fuel oil being introduced on the third hearth. No change was made in the furnace for this work except to replace parts of the upper brickwork with firebrick. Fig. 8 shows the tonnage fed to the furnace daily during the particular run with which the remainder of this paper chiefly deals. When the arms began to be buried the

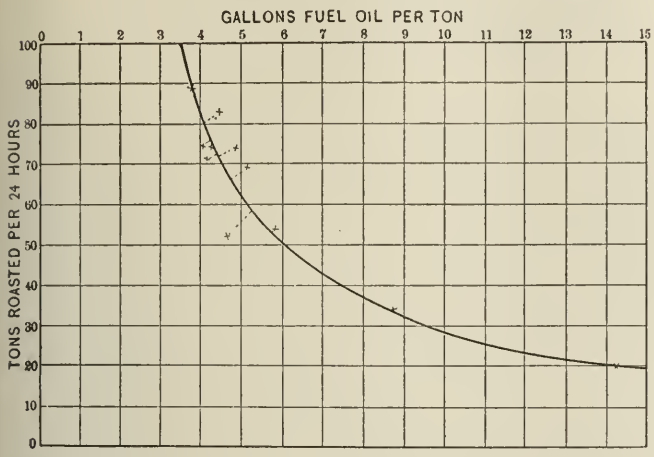


FIG. 9—ROASTER TONNAGE VS. FUEL-OIL CONSUMPTION

speed of rotation was increased from one revolution in 69 sec. to one in 60 sec. No trouble was experienced in the operation of the furnace.

Fig. 9 shows how the fuel-oil consumption was gradually cut down as the size of charge was increased. It is evident that 100 tons a day can be roasted with about 3.5 gal. of fuel oil per ton. The fuel oil burned was regulated so as to keep the maximum temperature on any hearth at about 950 deg. Fahr. Previous small-scale experiments had indicated that the proper roasting range lay between 900 deg. and 1100 deg. Fahr. Fig. 10 shows a log of the daily temperatures on the second, third, fourth and fifth hearths. It will be noted that the heat zone descended in the furnace as the tonnage

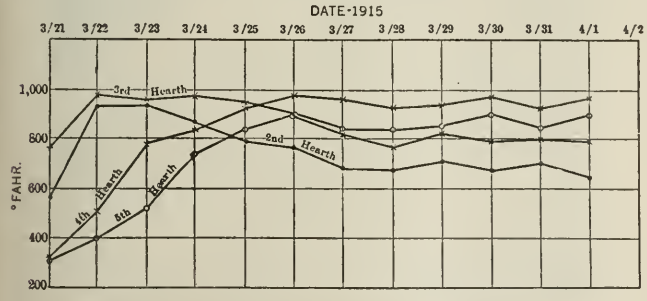


FIG. 10—ROASTER HEARTH TEMPERATURES

increased. This is shown diagrammatically in Fig. 11. At the same time the efficiency of the roast increased, as shown by Fig. 12. This is apparently due to the fact that at the higher rates, roasting temperatures were obtained on the fourth and fifth hearths, which were free from the more or less reducing atmosphere of the third and higher hearths due to the fuel oil.

Leaching

The hot calcines from the roaster were delivered through a spout casting made of Duriron into a rectangular trough about 30 ft. long, sloping 1¼ in. to the foot, which delivered directly into the first of the series of Dorr thickeners used for washing. This trough served three purposes: (1) that of leaching by agitation; (2) that of mechanically conveying the calcines from the roaster to the washing apparatus; and (3) that of absorbing the sensible heat of the calcines, thereby furnishing a warm liquor for electrolysis. A similar arrangement is described as doing excellent work in another field by Hofmann in his "Hydrometallurgy of Silver." A deep triangular trough was first constructed of common lumber. This was then lined with sheet lead

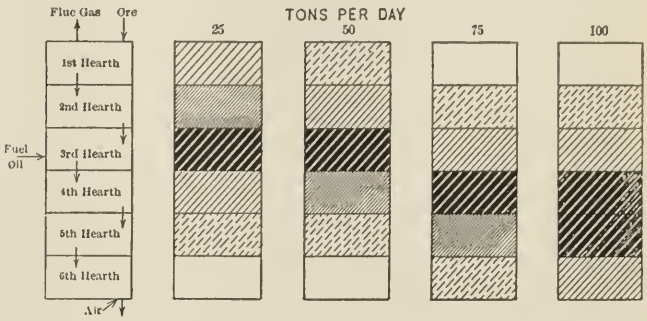


FIG. 11—ROASTER HEARTH TEMPERATURES

to make it liquor proof. Inside the lead lining, boards were loosely laid to prevent mechanical erosion of the lead by the calcines. A flat wooden cover was laid on top of the launder to keep down the steam and dust. This latter was not excessive, and would have been very slight had a more even delivery of calcines been made at the head of the sluice. The furnace arms alternated with light and heavy charges through the bottom drop hole and these were spread out over a reasonable time interval by placing an adjustable gate in the delivery spot, something on the plan of the classic hour glass. This worked fairly well, but it would have been better to have arranged some extra arms on the bottom hearth.

The copper content of the tailings at various points in their travel through the plant is shown in Fig. 13.

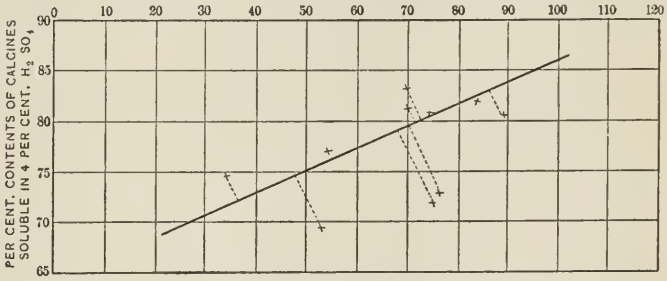


FIG. 12—VARIATION OF ROASTER EFFICIENCY WITH TONNAGE

The free sulphuric acid content of the liquor is shown in Fig. 14 and the effect of this strength of acid upon total extraction in Fig. 15.

The slimes as received assayed 0.84 per cent of copper. Fig. 15 shows that the calcines averaged about 0.74 per cent of copper, the grade falling as the furnace was gradually speeded up. This difference in assay was carefully investigated in the laboratory, and it seems very improbable that it was due to the formation of insoluble copper compounds during the roast, as three acids were used in the assay and various methods yielded but the merest traces of copper from the assay residue. The most probable explanation lies in the formation of particles of anhydrous copper sulphate during the roast, which blew over with the flue dust. No meas-

urements were made of the flue dust, as the furnace discharged into a common flue with other roasters treating concentrates.

The tails, as determined in the laboratory by heating samples of the calcines in 4 per cent sulphuric acid showed 0.2 per cent of copper, gradually dropping to 0.1 per cent as the furnace efficiency increased with the load. The actual final tails discharged from the last thickener ran about 0.1 per cent higher than the laboratory-leached calcines and laboratory tests showed this 0.1 per cent to be present as soluble copper. This same margin had been noted by Croasdale in his paper presented last year on his experiments at Ajo, and he there attributes it to the impossibility in practice of washing ore free from soluble salts. Fig. 15, however,

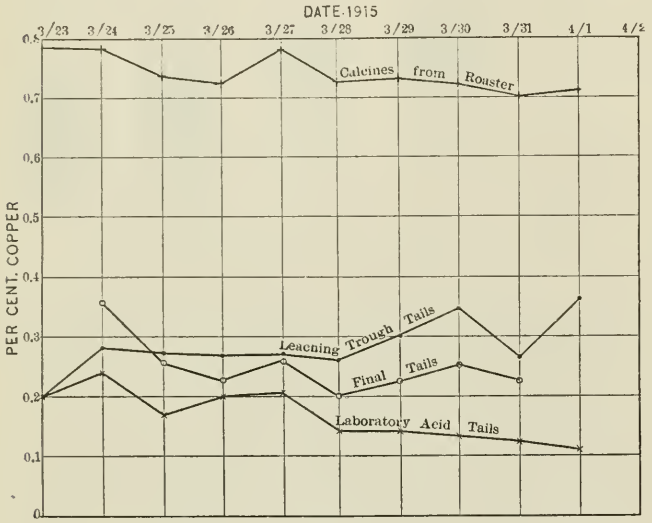

DATE-1915
3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2
PER CENT. COPPER
0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
Calcines from Rouster
Leaching Trough Tails
Final Tails
Laboratory Acid Tails

FIG. 13—COPPER CONTENT OF TAILINGS

seems to indicate that the difference in this case is largely due to the stronger acid liquor used in the laboratory tests.

Fig. 14 shows that the run was started with over 3 per cent of free sulphuric acid at the leaching trough and that this strength was allowed to exhaust itself gradually upon the entering ore as the run proceeded,

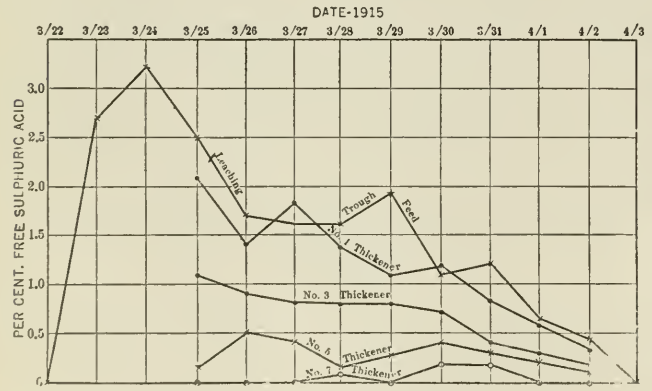

DATE-1915
3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3
PER CENT. FREE SULPHURIC ACID
3.0 2.5 2.0 1.5 1.0 0.5 0
Leaching Trough Feed
No. 1 Thickener
No. 3 Thickener
No. 5 Thickener
No. 7 Thickener

FIG. 14—ACID IN LIQUORS

the difference between final actual tails and laboratory tails increasing as the acid dropped. This same ratio is the basis of Fig. 14. It seems probable, therefore, that the strength of acid used will have to be considered in its bearing upon efficiency of extraction.

The leaching trough discharge ran but a few hundredths of a per cent higher in copper than the final tails after seven washings, showing that over 90 per cent of the leaching was done in the few seconds taken to travel down the trough. This high efficiency is due to the violent agitation when the hot calcines meet the relatively cool liquor, and to the fact that each particle of solid meets a fresh entering drop of liquor at the head of the trough, obtaining the full efficiency of the acid strength. An actual over-all extraction in practice somewhere in the seventies seems assured from these experiments.

Washing

The separation of the dissolved values from the exhausted slimes was one of the main problems presented. Any method of percolation was out of the question owing to the extremely fine state of subdivision of the material. The acid liquors employed, similarly ruled

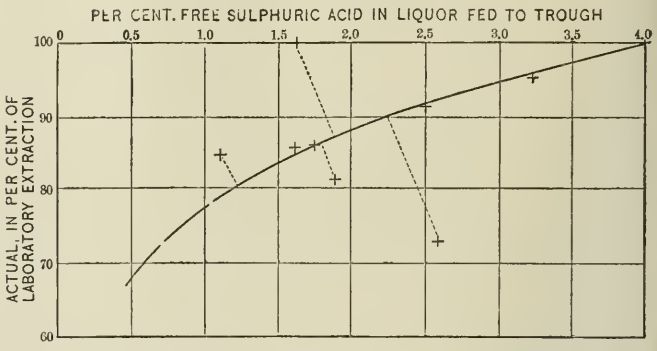

PER CENT. FREE SULPHURIC ACID IN LIQUOR FED TO TROUGH
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
ACTUAL, IN PER CENT. OF LABORATORY EXTRACTION
100 90 80 70 60

FIG. 15—FREE ACID IN LIQUOR VS. EFFICIENCY OF EXTRACTION

out many of the mechanical filters. It was finally decided to try out continuous counter-current decantation with Dorr thickeners of the acid-proof type of construction, some experience with which had been gained at the installation at the Butte-Duluth Mining Co.'s plant. Two 30 by 10 ft. and five 24 x 10 ft. tanks with suitable mechanisms and wood-stave pipes and fittings for 4-in. air lifts were therefore ordered and connected after erection in accordance with the flow sheet shown in Fig. 2.

The acid proofing of these mechanisms consisted of the substitution of wood for iron in the under-liquor parts. In turn, this called for some changes in design, two arms being used in place of four and the inclination

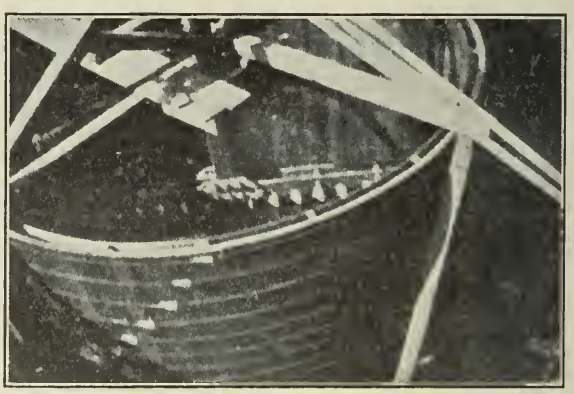


FIG. 16—THICKENER PADDLE

of the swept floor being lessened. Both these changes increased the digging load and the arms tended to ride rather than dig, extreme cases overstraining the unit. In spite of these difficulties the thickeners proved a practical apparatus. I believe, however, that the original metal construction properly protected by lead and equipped with Duriron rakes would be an improvement. An idea of the wooden construction can be obtained from Fig. 16.

The main difficulty was with the air lifts, and I am satisfied that these are not practical for the particular case. It must be remembered that it was desired to make an underflow of 50 per cent solids and that in the first thickeners many small lumps of slime had to be handled. When an air lift was gradually throttled until the desired thickness was obtained it no longer acted as a pump but more like a cannon, and a small capacity was obtained, finally resulting in one of two undesirable climaxes. Either a few small lumps settled out in the horizontal pipe under the tank, due to the slow flow, thereby choking it, or the lift would run thin for a moment followed by a rush as the normal pumping action was restored, stirring up the settled slimes and requiring constant attention for the next half hour in order to get the desired thickness of underflow. Also, the scouring action on the wood elbow at the point where the air was introduced was excessive, pipes sometimes wearing through in 24 hr.

Simple spigot discharge into a launder with some mechanical means of elevating was not promising, again due to obstructions making the flow of such a thick pulp very hard to regulate. Finally upon Mr. Dorr's suggestion two change were made: (1) a diaphragm pump was tried, and (2) the remaining air lifts were arranged to return a part of the underflow to the same tank, thereby increasing the solids moved and keeping the rate of flow in the horizontal feed pipe above the critical speed at which lumps settled out.

The diaphragm pump was an entire success. In the first place, the delivery depends almost entirely upon the stroke and speed and is not influenced by a momentary change in thickness as in the case of the air lift. Then the suction has the entire pressure of the atmosphere at its command and this is exerted whenever an obstruction is encountered. In fact, an ore sack and a pair of gloves were pumped up, to the surprise of the operator. It is astonishing how many things find their way into a system of this kind. A watch and fob and a brace and bit were among the articles added to our museum. Finally, the solids are moved steadily along and the scouring action is reduced to a degree which seems to make the use of wood pipe and fittings entirely practical. The pump was an ordinary 4-in. Gould contractor's pump with cast-iron body. The metal parts could readily be made of Duriron or other acid-resisting material.

During the run the temperature of the liquor in the first thickener gradually rose from 56 deg. Fahr. at the start until 100 deg. Fahr. was reached on the sixth day, at which point it was maintained by the sensible heat of the entering calcines. It was found possible to settle as high as 125 tons of solids in 24 hr. in one of the 30-ft. tanks. The overflow by actual test showed but 3 lb. of solids to the ton of liquor.

The liquors during the run accumulated sulphates corresponding to 10.0 lb. copper, 4.3 lb. iron, and 16.2 alumina per ton of slimes leached. The actual acid consumed was 49.0 lb. The acid equivalent of the corresponding metallic oxides is 70.5 lb., showing the presence of considerable sulphates in the calcines. A laboratory test on the calcines, using 4 per cent acid, showed a consumption of 68.9 lb. and a similar test on the product of a small-scale roast 69.1 lb. acid per ton. It appears, therefore, that less acid will be used in practice than in laboratory tests. Unfortunately, the run was not sufficiently prolonged to determine whether the proportion of impurities dissolved decreased as the liquors became more concentrated.

The Arizona Copper Co. produced 1758 tons of copper in May, 1915.

Metastability of Metals

BY A. VOSMAER

From more than one point of view it is important to recognize that metals are not always as stable substances as they appear to be. Professor E. Cohen of the Van't Hoff Laboratory, Utrecht, Holland, has carried out a large number of experiments bearing on the subject of metastability of metals and is continuing that work so that we may hope to have this difficult problem fully elucidated. It will be interesting and useful to the readers of this paper to be posted on the subject of allotropy of metals, since many a mystery in the world of metals has ceased to be such when the question of molecular transformation was considered.

The transformations of metalloids, such as carbon, phosphorus, sulphur from one modification into another are familiar to most people, but not so the transformations of metals which, by the way, are usually much less marked.

The man who, in a cold winter, buys a lot of block tin to store it away, runs the risk of finding a mass of grey powder after some time, instead of the solid white blocks. In fact, this did occur in Europe in the winter of 1858 and gave rise to the rather difficult question, whether or not tin in the white and in the grey state is one and the same substance. From a chemical standpoint it certainly is, but from a physical standpoint it certainly is not.

In fact, since we now have to admit that iron in the magnetized and the same in the nonmagnetized condition cannot be called one and the same substance, the problem of defining substances becomes a more and more difficult task for the scientist and it has also a practical importance in the industry. For it should be borne in mind that scientific research work can be of great benefit to the practical man, since the theory of metals and alloys not only explains mysteries and faults, but it also prevents mistakes and may even cure them.

The Van't Hoff Laboratory, through its head, Professor Cohen, has undertaken to study the question of metastability of metals and from the results published in the Royal Academy of Science of Amsterdam, we have prepared the following abstracts which give the gist of the results.

Allotropy of Bismuth[1]

Dilatometric research showed a sudden change in volume at a temperature of about 75 deg. C., when the alpha bismuth, stable at temperatures below 75 deg. C. changes into the beta bismuth, stable at temperatures above 75 deg. C. The alpha bismuth has a specific gravity of 9.732, the beta form 9.712. This is a considerable difference; it confirms the results of the dilatometric measurements which showed that the change from alpha to beta is accompanied by an increase in volume.

If we bear in mind that the beta bismuth differs in properties from the alpha modification and also that these molecular rearrangements take considerable time at temperatures lower than the transformation temperature proper, it is clear that as a rule commercial bismuth will always consist of a mixture of both modifications tending to reach equilibrium.

This explains why the physical constants of bismuth are as yet very far from being constant. Since the beta bismuth is a better electrical conductor than alpha bismuth, the specific conductivity of any sample of bismuth is bound to vary according to the ratio of alpha to beta bismuth in the sample.

Although the transition point is well defined at 75 deg. C., this does not mean that bismuth at a lower tem-

[1]Communication of June, 1913.

perature does not contain any beta metal. On the contrary, as a rule all bismuth will always contain some beta, as this form can very well exist in metastable condition.

On the other hand, it is noteworthy that the alpha bismuth may very well exist in metastable condition at temperatures above the transition point, even at temperatures as high as 150 deg. C.

In 1899 Perrot published his experience that the thermo electric potential of cast bismuth changes after some time without any apparent cause. Now we know from Cohen's investigation that this strange behavior of bismuth is not strange at all. Perrot's bismuth evidently contained some beta bismuth which slowly but surely turned to the stable alpha bismuth condition.

Determinations of the specific gravity, the melting point, the Hall effect, etc., have to be revised. All properties of bismuth hitherto determined except the atomic weight, must of necessity be corrected because not until 1913 was it known that all bismuth experimented upon may have consisted of a mixture—an undefined mixture —of alpha and beta bismuth.

We should remember the big difference between metals or alloys in the fluid state and in the solid state. It may very well be that in the fluid state all of the metal will be in the beta condition. On cooling down not all of the beta bismuth can find time to be converted to alpha bismuth and the beta condition is kept to a considerable extent in that form.

From a technical standpoint the change of specific gravity can be made use of. Every one familiar with castings knows the trouble caused by shrinkage; now bismuth and bismuth alloys possess the valuable property to expand on solidification, this, of course, gives rise to very sharp castings. It may be added that many of the fine Chinese metal castings of small objects for ornamental use contain bismuth. Unfortunately said change in volume—slight expansion on cooling—as observed by practical men in casting, cannot be explained by the allotropic change from beta to alpha bismuth at 75 deg. because it occurs at a much higher temperature and in a reverse sense.

It may be that there still is a third modification, gamma, of smaller specific volume than the beta and a second transition point a little below the melting point, but reports on bismuth do not mention this supposed third modification.

Allotropy of Antimony[2]

There have been four different forms of antimony known for some years, but the correlation of these has not yet been established.

Cohen investigated in how far commercial antimony, also known as metallic antimony, is to be considered as a metastable system and he came to the conclusion that it is metastable.

The four allotropic modifications of antimony are the ordinary or metallic, the black, the yellow and the explosive. The latter three are all metastable at ordinary temperatures.

Cohen's determinations of density led him to say that antimony after chilling, is in a form which changes at 100 deg. C., with a measurable velocity into a mass of different density. Probably about 96 deg. C. is the transition temperature.

The conclusion of this preliminary work is that antimony, as it is known in the familiar form, is a metastable system which consists of more than two allotropic forms. This is important in view of the extended use of antimony for alloys in technical arts.

Metals and alloys are judged, tested and paid for according to their properties and qualities. In case of dispute between buyer and seller in regard to quality the greatest embarrassment arises when authorities do not agree upon figures. But this will be unavoidable if metals are no longer what we think or thought them to be—definite substances. If a metal is a system of undefined composition as regards its own allotropic modifications, then we need not wonder about the discrepancies in physical constants and it is of the highest importance that the metal trade takes notice of the difficulties which may become traps in establishing definite figures.

[2]Communicated Oct., 1914.

Allotropy of Potassium[3]

Potassium is a metal of only very small importance for industrial uses and probably never will play an important rôle, but it is of interest to know that this metal also is subject to allotropic modification. The metal potassium as it has hitherto been known is at ordinary temperatures a metastable system in consequence of the simultaneous presence of two forms, alpha and beta potassium.

Allotropy of Copper[4]

It may surprise many people to learn that also in the case of copper we have a metal containing both alpha and beta copper, the transformation temperature being between 69.2 deg. and 71.7 deg. C.

In this, as in all cases, the transformation velocity depends largely on the presence of an electrolyte or of powdered metal which act as catalyzers. Under normal conditions the change of beta into alpha copper is so slow that it escapes notice unless specially looked for.

Remembering the changes undergone by tin and by zinc it is to be expected that bronzes and brasses will be subject to change as well.

Chemical Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

This is a subject on which a number of large volumes have been written, but none of them have succeeded in elucidating the subject in such a way as to coordinate the accepted theories and the facts of practice to a profoundly useful extent. At the same time honor must be done to the work of some for their investigations which helped to lay the foundation, although not precisely for the structure which they had in mind.

Sir I. Lothian Bell in particular found time in a busy and highly successful commercial life to prosecute extensive investigations, to ponder at great length, and to record accurately the results of his labors in two large volumes in which I believe it is admitted that the first reasonably successful attempt was made to write a heat equation of the blast furnace. Most unfortunately for him and his disciples there are not one but two heat equations of the blast furnace, and in endeavoring to square all the conditions with this one equation he was led into errors which went far to vitiate the value of his work. But as a pioneer in applying chemistry and quantitative heat values to the operations of the furnace he is deserving of his high place in the esteem of furnacemen.

Gruner also set forth in 1879 the ideal condition of working of a blast furnace which has been too little heeded and has even been attacked in recent years as not universally correct, but I think I shall be able to show that Gruner is right and that his critic, through not realizing all the conditions, has fallen into error.

The action of the blast furnace must be considered in

[3]Communicated Feb., 1915.

[4]Communicated Dec., 1913; May, 1914.

three different aspects which sometimes merge into one another, but nevertheless can best be considered separately at first, the chemical, the thermal and the mechanical; in which order we shall consider them.

The Different Regions of the Furnace

An outline of a typical modern blast furnace is seen in Fig. 1. The cylindrical straight portion at the bottom is called the hearth or crucible or sometimes the well because it serves to contain the liquid iron and slag. The divergent cone above this is called the bosh. The short cylindrical portion and the long convergent cone above this, surmounted by another cylinder has so far as known to me no name established by universal custom, and I have been accustomed to call it the shaft, since the furnace as a whole is a "shaft" furnace and it is obviously this portion which gives it that name.

The furnace is expected to be kept filled to the line

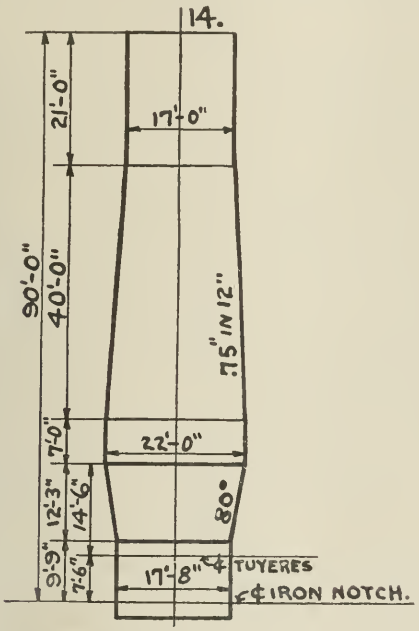


FIG. 1—LINES OF A MODERN BLAST FURNACE (SOUTH CHICAGO, NO. 4, 1914)

in the upper cylinder marked "stock line" and this is the diameter which is meant by the "stock-line diameter."

The height of furnaces, in the days of hand filling, was always measured from the hearth bottom to the top of the filling platform, but since the decline of hand filling the top platform is not quite such a definite and important level, having nothing to do with the level from which filling is done in mechanical charging, so it is better now to give the height to the bottom of the supporting collar on the hopper as that corresponds more nearly to the old top platform than any other equally definite point.

The size of furnaces is given by their height and diameter at the top of the bosh, very frequently the diameter of the hearth and stock line are added in the order given.

This terminology suffers from one defect. The word "hearth" denotes the level at which combustion takes place and connotes the laboratory of the apparatus in which the active work is done, but the region of the furnace which corresponds to this description is really the bosh, because the hearth, so-called, is generally filled (or largely so) with molten material, and combustion to any considerable extent cannot take place there in any event, since there is no outlet for the blast in any direction but upward, so that instantly on leaving the tuyeres the blast must pass up into the bosh, where it burns the coke and where most of the final work of the furnace is done. This should obviously be called the "hearth," if any region is to have that name. The habit of thinking and speaking of what goes on "in the hearth" is so universal among furnacemen that it is almost impossible to avoid using the word "hearth" in the sense of the laboratory of the furnace. I shall avoid confusion on this score to the best of my ability, but the reader should be on guard against the ever-present possibility of confusion from this source.

In the introductory chapter of this serial the general outlines and requirements of the process were set forth, and need not be repeated here. In operation the oxygen of the blast is burned by the fuel of the charge to CO in the bosh of the furnace. Theoretically oxygen first burns to CO_2 and then absorbs an additional atom of carbon which converts it into CO, since CO_2 cannot exist as such with carbon except at temperatures far lower than those in the hearth of a blast furnace. Practically the absorption of the additional atom of carbon takes place so quickly that no CO_2 has even been found excepting exceedingly close to the tuyeres and the physical difficulties of taking a correct sample of gas under the conditions existing are so great that little reliable work has ever been done to determine the limit within which the reaction occurs. I was formerly inclined to believe that for practical purposes the formation of CO_2 might be disregarded and the subject considered only on the basis of a direct formation of CO. Professor Howe, however, has pointed out to me that one of the observed facts of practice is well explained by assuming a zone of CO_2 formation at the tuyeres.

I shall later set forth the opinion that combustion of the oxygen to CO is not complete until the gas (blast) reaches the top of the bosh. If this be true and there were not a zone of CO_2 formation then the temperature would be virtually the same at the tuyeres as at the top of the bosh and this we know most positively is not true. There is a zone of intensest temperature right around the tuyeres which drops rapidly at first and then more slowly as we ascend.

These statements do not, unfortunately, depend greatly upon pyrometric measurements at different levels because the conditions of temperature, pressure and dripping iron and cinder within the furnace make such measurements in this zone almost if not quite impossible; the statements depend upon observation of the wear and the evidences of fusion at different levels in furnaces after they have been blown out, and general observation and experience with furnaces in operation.

The amount of heat developed by the combustion of a given quantity of oxygen to CO is only six-tenths of that developed by its combustion to CO_2 and the reaction $CO_2 + C = 2CO$ absorbs a large quantity of heat, hence combustion to CO_2 followed by instant conversion to CO would give a hot zone succeeded by a relatively much cooler one, the condition which we find in practice and for which we have no other adequate explanation. We are ,therefore, compelled to believe that at least part of the oxygen of the blast is converted to CO_2 and remains in that condition long enough to affect the temperature of the tuyere zone through the interval must be measured in hundredths if not thousandths of a second.

As far as the total heat developed in the hearth and the gas discharged into the shaft from the bosh is concerned the combustion to CO_2 has no effect, for in coming back from CO_2 to CO the heat absorbed is precisely the excess developed by consumption to CO_2 over that to CO, and the effect in the final result is therefore zero. Whether any effect of this narrow zone of high temper-

ature and relatively oxidizing condition can be determined may be left for later discussion and we need only say now that the ultimate reaction between the oxygen of the blast and the fuel in the bosh is to convert both to CO, with the development of a certain amount of heat, which is needed to complete the smelting operation, the nitrogen simply serving as a useless load to be carried.

The CO produced in the hearth and bosh passes up through the shaft of the furnace and with more or less help from the solid carbon of the charge reduces the iron from the oxide to the metallic state according to certain reactions which we may now discuss leaving for later discussion the question of heat development.

The functions of these two portions of the furnace, the shaft and the bosh, are quite separate and distinct so much so that we could substitute some other apparatus for one and leave the other unaffected.

For instance, we could produce iron sponge by reduction with a reducing flame in a rotary kiln and introduce it into the "bosh" of a furnace with no shaft above it and there melt the sponge to produce liquid iron and slag.

On the other hand, we could conceivably extract the iron sponge from the shaft of the blast furnace just above the bosh and then melt it down in an open-hearth or other melting furnace.

Many such processes have been tried and some of the attempts have succeeded technically although none of them have survived in actual use for they could not meet the commercial conditions.

They serve a useful purpose here by furnishing proof that the function of the blast furnace is not a single but a double one for the performance of two separate and distinct operations. There is in my opinion no such thing as a fundamentally correct understanding of blast-furnace principles without a full realization of this fact.

The Chemical Principles

The number of reactions which actually take place within the blast furnace is almost unlimited, but those which control its action are relatively few and simple.

These are the reactions between carbon, oxygen, and iron and its oxides, and the reactions which lead to the formation of slag, which are principally the formation of silicates and aluminate of bases, generally in fact almost universally lime and magnesia.

THE REACTIONS BETWEEN CARBON AND ITS OXIDES AND IRON AND ITS OXIDES

There are three well recognized oxides of iron which are in the order of their oxygen contents: Ferric oxide Fe_2O_3, ferric-ferrous, magnetic or black oxide Fe_3O_4, and ferrous oxide FeO.

The former is normally blood red in a color and very slightly magnetic under even the most powerful magnetic field, and is the commonest form in which iron occurs in nature. When hydrated it is brown in color and commonly known as limonite. The second is black and more highly magnetic than any other natural mineral, it is the second commonest form of iron oxide, and that to which iron oxidizes when heated.

The third, ferrous oxide FeO, is unstable under atmospheric conditions, and seizing oxygen from the air instantly returns to the form of ferric oxide.

The oxides of carbon are two, carbon monoxide CO and carbon dioxide CO_2, both gaseous at temperatures even far below that of the atmosphere.

These two elements and their five oxides react with one another at various temperatures according to the following equations in which the modern symbols are used to show that they are reversible:

$$3Fe_2O_3 + CO \rightleftarrows 2Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO \rightleftarrows 3FeO + CO_2$$
$$FeO + CO \rightleftarrows Fe + CO_2$$
$$3Fe_2O_3 + C \rightleftarrows 2Fe_3O_4 + CO$$
$$Fe_3O_4 + C \rightleftarrows 3FeO + CO$$
$$FeO + C \rightleftarrows Fe + CO$$

It may well be doubted whether the reduction of Fe_2O_3 to FeO takes place by way of Fe_3O_4, and I have always held the most serious doubts as to this point for two reasons: First, the relative complexity of the reaction involving three molecules of one oxide and two of the other, as compared with the extremely simple reactions

$$Fe_2O_3 + C = 2FeO + CO$$
$$Fe_2O_3 + CO = 2FeO + CO_2$$

which involve only one of each. Second, I have always found that the magnetic oxide is less reducible in the furnace than ferric oxide, and it is difficult for me to see how this could be so if ferric oxide has to pass through the magnetic oxide stage during reduction, and I have for several years past rejected that idea.

On the other hand, it is claimed that magnetic oxide is not irreducible in itself, but only because it is extremely dense and non-porous, so that the gas gets no opportunity to work on anything but its exposed surface. That magnetite is generally very dense is certainly true, but even in an extremely fine state of subdivision like roll scale or some of the Lake ores which are composed of flakes almost like graphite this oxide has a strong tendency to scour the furnace, that is, to come through only partly reduced and uniting with the slag forms a silicate of iron which always has an extremely scouring action.

On the other hand, again, Prof. H. O. Hofman of the Massachusetts Institute of Technology has told me that there are several arrests in the curve giving the relation between temperature and deoxidation of iron which indicate the existence of several intermediate oxides between those here noted, and the fact that iron in the course of reduction passes through these subordinate states of oxidation would indicate that it would also pass through the state of Fe_3O_4.

Testimony from such an authority cannot be questioned, but even admitting this as a laboratory condition it does not follow that the same thing takes place in the furnace, and certainly the reputation of magnetic oxide as an ore is not good among furnacemen on account of its well-recognized irreducibility, and I cannot believe that reduction of ferric oxide takes place principally by way of Fe_3O_4.

Carbon unites with oxygen according to three well-known equations as follows:

$$2C + O_2 \rightleftarrows 2CO$$
$$2CO + O_2 \rightleftarrows 2CO_2$$
$$CO_2 + C \rightleftarrows 2CO$$

all of which are reversible.

As the two oxides of carbon occur in the blast furnace in all concentrations from CO alone to CO and CO_2 in about equal proportions and through a very wide range of temperatures, we have the iron and its oxides exposed simultaneously to influences which tend to oxidize them and to those which reduce them.

The question of the temperatures and concentrations of the two oxides of carbon with which carbon is in equilibrium has been experimentally investigated by O. Boudouard in France, and the equilibrium condition of the iron and its oxides in the presence of varying percentages CO and CO_2 at different temperatures has been experimentally investigated by Baur and Glaessner in Germany and reported by them in *Stahl und Eisen* for May 1, 1903.

The work of Baur and Glaessner was extensive and ighly creditable. The data given are of great value, ut must not be used recklessly, as they cannot always e applied directly to the solution of practical problems hose conditions are frequently very different from hose which it is necessary to create in order to secure cientific results. In the present case the scientific nvestigation has sought equilibrium conditions which re only established after many hours, whereas in the last furnace the total time of passage of the gas from ts entrance at the tuyeres to its exit at the top is only few seconds, during which equilibrium in most reac- ions is not even approximated.

We can, therefore, use the valuable diagram of Baur nd Glaessner to show what *tends* to happen and what *annot* happen, but we should be led far astray if we ried to use its results to show the extent to which most f these reactions actually take place.

Their results are given by Sir William Ramsay in is work on "The Phase Rule," from which the follow- ng extract is taken as it is the only condensed and yet ogical statement extant with which I am familiar of very complex set of conditions:

"Some of the most important systems of three com- onents in which equilibrium exists between solid and as phases are those formed by the three components— ron, carbon monoxide, and carbon dioxide—and they re of importance especially for the study of the proc- sses occurring in the blast furnace.

"If carbon monoxide is passed over reduced iron owder at a temperature of about 600 deg., the iron is xidized and the carbon monoxide reduced with separa- ion of carbon in accordance with the equation

$$Fe + CO = FeO + C$$

his reaction is succeeded by the two reactions

$$FeO + CO = Fe + CO_2$$

$$CO_2 + C = 2CO$$

"The former of these reactions is not complete, but eads to a definite equilibrium. The result of the differ- nt reactions is therefore an equilibrium between the hree solid phases, carbon, iron, and ferrous oxide, and he gas phase consisting of carbon monoxide and dioxide. Ve have here four phases, and if the total pressure is aintained constant, equilibrium can occur only at a efinite temperature.

"Since, under certain conditions, we can also have the eaction

$$Fe_3O_4 + CO = 3FeO + CO_2$$

second series of equilibria can be obtained of a char- ter similar to the former. These various equilibria ave been investigated by Baur and Glaessner and ie following is a short account of the results of their ork.

"Mixtures of the solid phases in equilibrium with rbon monoxide and dioxide were heated in a porcelain ibe at a definite temperature until equilibrium was oduced, and the gas was then pumped off and ana- zed. The results which were obtained are given in ables I and II and represented graphically in Fig. 2.

"As is evident from Tables I and II and from the rves in Fig. 2, the curve of equilibrium in the case the reaction

$$Fe_3O_4 + CO = 3FeO + CO_2$$

hibits a maximum for the ratio $CO : CO_2$, at 490 deg., hile for the reaction

$$FeO + CO = Fe + CO_2$$

is ratio has a minimum value of 680 deg. From these rves can be derived the conditions under which the fferent solid phases can exist in contact with gas. hus, for example, at a temperature of 690 deg., FeO d Fe_3O_4 can coexist with a mixture of 65.5 per cent of CO_2 and 34.5 per cent of CO. If the partial pressure of CO_2 is increased, there occurs the reaction

$$3FeO + CO_2 = Fe_3O_4 + CO$$

and if carbon dioxide is added in sufficient amount, the ferrous oxide finally disappears completely. If, on the other hand, the partial pressure of CO is increased, there occurs the reaction

$$Fe_3O_4 + CO = 3FeO + CO_2$$

and all the ferric oxide can be made to disappear. We see, therefore, that Fe_3O_4 can only exist at temperatures and in contact with mixtures of carbon monoxide and dioxide, represented by the area which lies below the under curve in Fig. 2. Similarly, the region of existence of FeO is that represented by the area between the

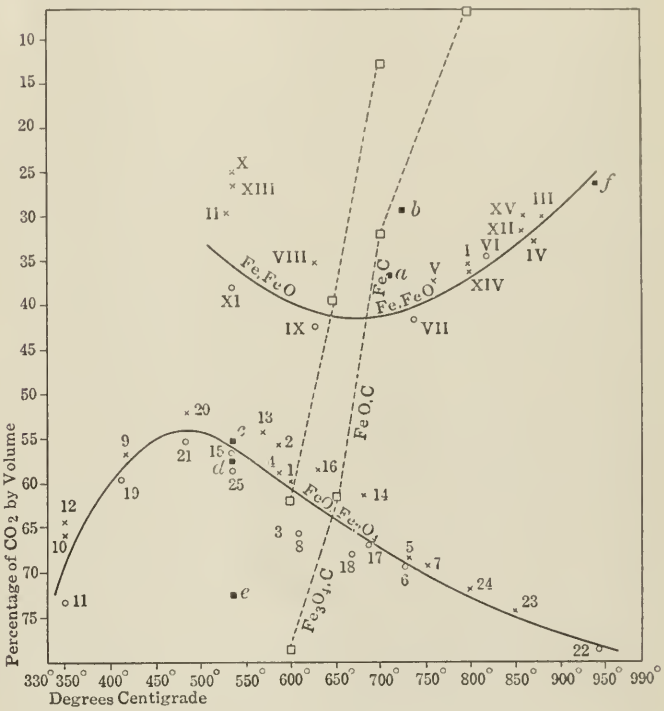


FIG. 2—EQUILIBRIUM CURVE

two curves, while metallic iron can exist under the conditions of temperature and composition of gas phase represented by the area above the upper curve in Fig. 2. If, therefore, ferric oxide or metallic iron is heated for a sufficiently long time at temperatures above 700 deg. (to the right of the dotted line, *vide infra*), complete transformation to ferrous oxide finally occurs.

"In another series of equilibria which can be obtained, carbon is one of the solid phases. In Fig. 2 the equilibria between carbon, carbon monoxide, and carbon dioxide under pressures of one and of a quarter atmosphere, are represented by dotted lines[1].

"If we consider only the dotted line on the right, representing the equilibria under atmospheric pressure, we see that the points in which the dotted line cuts the other two curves must represent systems in which carbon monoxide and carbon dioxide are in equilibrium with $FeO + Fe_3O_4 + C$, on the one hand, and with $Fe + FeO + C$ on the other. These systems can only exist at one definite temperature, if we make the restriction that the pressure is maintained constant (atmospheric pressure). Starting, therefore, with the equilibrium $FeO + Fe_3O_4 + CO + CO_2$ at a temperature of about 670 deg., and then add carbon to the system, the reaction

$$C + CO_2 = 2CO$$

will occur, because the concentration of CO_2 is greater

[1]These equilibria were obtained by Boudouard, *Annales chim. phys.*, 1901 [7], 24, 5. See also Hahn, *Zeitschr. physikal. Chem.*, 1903, 42, 705; 44, 513. Rhead and Wheeler, *Jour. Chem. Soc.*, 1910, 97, 2178.

than what corresponds with the system $FeO + Fe_2O_4 + C$ in equilibrium with carbon monoxide and dioxide. In consequence of this reaction, the equilibrium between $FeO + Fe_3O_4$ and the gas phase is disturbed, and the change in the composition of the gas phase is opposed by the reaction $Fe_3O_4 + CO = 3FeO + CO_2$, which continues until either all the carbon or all the ferric oxide is used up. If the ferric oxide first disappears, the equilibrium corresponds with a point on the dotted line in the middle area of Fig. 2, which represents equilibria between $FeO + C$ as solid phases, and a mixture of carbon monoxide and dioxide as gas phase. If the temperature is higher than 685 deg., at which temperature the curve for $C — CO — CO_2$ cuts that for $Fe — FeO — CO — CO_2$, then, when all the ferric oxide has disappeared, the concentration of CO_2 is still too great for the coexistence of FeO and C. Consequently, there occurs the reaction $C + CO_2 = 2CO$, and the composition of the gas phase alters until a point on the upper curve is reached. A further increase in the concentration of CO is opposed by the reaction $FeO + CO = Fe + CO_2$, and the pressure remains constant until all the ferrous oxide is reduced and only iron and carbon remain in equilibrium with gas. If the quantities of the substances have been rightly chosen, we ultimately reach a point on the dotted curve in the upper part of Fig. 2.

"Fig. 2 shows us, also, what are the conditions under which the reduction of ferric to ferrous oxide by carbon can occur. Let us suppose, for example, that we start with a mixture of carbon monoxide and dioxide at about 600 deg. (the lowest point on the dotted line), and maintain the total pressure constant and equal to one atmosphere. If the temperature is increased, the concentration of the carbon dioxide will diminish, owing to the reaction $C + CO_2 = 2CO$, but the ferric oxide will undergo no change until the temperature reaches 647 deg., the point of intersection of the dotted curve with the curve for FeO and Fe_3O_4. At this point further increase in the concentration of carbon monoxide is opposed by the reduction of ferric oxide in accordance with the equation $Fe_3O_4 + CO = 3FeO + CO_2$. The pressure, therefore, remains constant until all the ferric oxide has disappeared. If the temperature is still further raised, we again obtain a univariant system, $FeO + C$, in equilibrium with gas (univariant because the total pressure is constant), and if the temperature is raised the composition of the gas must undergo change. This is effected by the reaction $C + CO_2 = 2CO$. When the temperature rises to 685 deg., at which the dotted curve cuts the curve for $Fe — FeO$, further change is prevented by the reaction $FeO + CO = Fe + CO_2$, When all the ferrous oxide is used up, we obtain the system $Fe + C$ in equilibrium with gas. If the temperature is now raised, the composition of the gas undergoes change, as shown by the dotted line. The two temperatures, 647 deg. and 685 deg., give, evidently, the limits within which ferric or ferrous oxide can be reduced directly by carbon.

"It is further evident that at any temperature to the right of the dotted line, carbon is unstable in presence of iron or its oxides, while at temperatures lower than those represented by the dotted line it is stable. In the blast furnace, therefore, separation of carbon can occur only at lower temperatures, and the carbon must disappear on raising the temperature.

"Finally, it may be remarked that the equilibrium curves show that ferrous oxide is most easily reduced at 680 deg., since the concentration of the carbon monoxide required at this temperature is a minimum. On the other hand, ferric oxide is reduced with greatest difficulty at 490 deg., since at this temperature the requisite concentration of carbon monoxide is a maximum."

Table I—Solid Phases: Fe_3O_4; FeO.

No.	Tube filled with	Duration of the experiment in hours.	Temperature.	Percentage of CO_2	Percentage of CO
1	CO	14	600°	59.3	40.7
2	CO	15	590°	54.7	45.3
3	CO_2	16	590°	64.6	35.4
4	CO	24	590°	58.4	41.6
5	CO	22	730°	67.7	32.3
6	CO_2	22	730°	86.1	31.9
7	CO	22	750°	68.4	31.6
8	CO_2	22	610°	64.9	35.1
9	CO	23	420°	56.0	44.0
10	CO	47	350°	65.6	34.4
11	CO_2	46	350°	72.8	27.2
12	CO	53	350°	64.0	36.0
13	CO	18	570°	53.4	46.6
14	CO	19	680°	60.5	39.5
15	CO_2	24	540°	55.5	44.5
16	CO	21	630°	57.5	42.5
17	CO_2	17	690°	65.5	34.5
18	CO_2	17	670°	67.0	33.0
19	CO_2	24	410°	58.5	41.5
20	CO	24	490°	51.7	48.8
21	CO_2	23	590°	54.4	45.6
22	CO_2	4	950°	77.0	23.0
23	CO_2	15	850°	73.4	26.6
24	CO	8	800°	71.2	28.8
25	CO_2	24	540°	56.7	43.3

Table II—Solid Phases: FeO; Fe.

No.	Tube filled with	Duration of the experiment in hours.	Temperature.	Percentage of CO_2	Percentage of CO
I.	CO	15	800°	35.2	64.8
II.	CO	18	530°	29.1	70.9
III.	CO	13	880°	30.2	69.6
IV.	CO_2	24	870°	32.3	67.7
V.	CO	18	760°	36.9	63.1
VI.	CO_2	16	820°	34.7	65.3
VII.	CO_2	18	730°	41.1	58.9
VIII.	CO	18	630°	34.9	65.1
IX.	CO_2	17	630°	61.6	58.4
X.	CO	18	540°	25.0	75.0
XI.	CO_2	25	540°	36.5	63.5

While the whole series of reactions between iron and carbon and their oxides are graphically portrayed in the chart of Fig. 2 and the accompanying explanation, the form in which the explanation exists is rather condensed and it may be well to run over some of the more important reactions in their relation to the more important phases of the operation of the furnace.

The reduction of iron oxide to iron is performed principally by carbon monoxide, but partly by solid carbon. The more complete is the reduction by CO the more efficient is the operation. The reason for this is not immediately apparent, but will be explained in detail in the next chapter. Part of the CO_2 so formed picks up carbon from the fuel and reconverts itself into CO; on the other hand, the CO is in part split up by what is supposed to be a catalytic action of the iron oxide according to the equation $2CO = CO_2 + C$. The carbon so deposited is in the form of an impalpable powder, which being a solid travels down with the stock, while the gas whose splitting up deposited it, passes on up and out of the furnace. At lower levels where the temperatures are higher and a smaller concentration of CO_2 can remain in equilibrium with carbon this carbon dust is dissolved by the reaction of $C + CO_2 = 2CO$ and passes up again with the gas. We have then a never-ending conflict of conditions in the shaft of the furnace with first one reaction occurring and then the opposite one wiping out its effects.

The effect of having deposited carbon carried down in the solid state through a given zone and carried up as gas to be redeposited again at the top of this zone is to produce an excess of this carbon dust in this zone, which tends to obstruct the openings in the stock through which the gas must pass and causes the furnace to work "tight" in this zone, and most furnaces which slip with more or less regularity in normal operation do so from about the same depth, as measured by the violence of the slip and the effect on the furnace. Such slips throw out huge clouds of black dust which travels high in the air; part of this is undoubtedly partly reduced iron, but much of it is the carbon dust which caused the slip in many cases.

While discussing the subject of the conflicting conditions existing in the shaft of the furnace it is well to call attention to the fact that the stock is charged in roughly horizontal layers, first one of fuel, then one of ore and stone, one of which tends to reduce the CO_2 already formed to CO, while the other tends to oxidize the CO to CO_2. These layers are only a foot or so in thickness, and the time of the passage of the gas through them must be measured in hundredths of a second so their effect is like that of waves of alternating forces, one set trying to hinder, the other to assist in bringing about the equilibrium which the broader conditions of temperature, etc., are trying to establish. This in itself would constitute a sufficient reason for the impossibility of predicting the conditions which will prevail under any given circumstances by the equilibrium diagram.

The Real Controlling Factor in the Composition of the Top Gas

After all the laborious and painstaking investigations of this subject which have been made we come now to the astonishing fact that the composition of the top gases is not a cause but an effect, and that important as are the detailed reactions I have so briefly described the composition of the top gas does not depend on them primarily at all, and at least three-fourths of all the work done on that subject has been wasted.

The reason for this will be clearer after we have discussed the heat equation of the furnace, but it will be well to explain it now and then return to it again later if desired. The reason is this: The ore to produce a ton of iron contains a certain definite quantity of oxygen; ferric oxide contains 70 per cent Fe and 30 per cent O, magnetic oxide Fe_3O_4 contains 72.4 per cent Fe and 27.6 per cent O, but commercial pig iron only contains about 94 cent Fe, and this being accompanied by 35.8 per cent of its weight of oxygen in the case of magnetite and 40.3 per cent in the case of ferric oxide, the oxygen per unit of pig iron is 33.7 per cent in the first case and 38 per cent in the second. These are perfectly definite relations not subject to furnace conditions or other qualifications.

We shall presently see that to keep the furnace hot enough in the hearth to run, a certain amount of fuel must be burned in the hearth for every unit of iron produced, the amount having nothing to do with reduction or in a general way with chemistry at all, but being a plain matter of heat, as the case of melting ice or any other solid. Now this carbon is burned to CO and nothing else; the CO_2 phase is, as I have explained, a transient one without effect on the final result. Thus we have a certain definite amount of carbon monoxide depending entirely upon hearth conditions and a certain definite quantity of oxygen added to it, as the oxygen is removed from the ore during the upward passage of the gas. It is obviously no problem in chemistry, but only a rudimentary one in arithmetic as to what the result will be in the composition of the gas at the furnace top.

But this statement which would settle so many problems if it were unreservedly true is subject to a certain limitation. The amount of carbon which must be burned in the hearth is not the same as the amount which is charged into the top, nor does it even bear a fixed relation with it, because the carbon charged, from the moment it enters the furnace, is subject to the solution by the CO_2 in the gas, and to direct oxidation by the oxygen of the ore and these influences, particularly the latter, as I shall presently show, are extremely variable, so that though the oxygen liberated and the carbon burned in the hearth per unit of iron produced are definite quantities which by themselves would give a top gas of a certain definite composition, they are not the sole determining factors; a secondary but none the less considerable influence is exerted by the carbon dissolved before it reached the tuyeres. This constitutes a variable addition of carbon to the definite composition of gas produced by the two main factors.

The Solution of the Carbon

The flux used for blast furnaces is universally either carbonate of lime, calcite or carbonate of lime and magnesia, dolomite, or a mixture of these two. These carbonates are broken up by heat, the carbon dioxide beginning to come off at a temperature of 800 deg. Fahr. or so, and not being all driven off, especially in the case of dolomite, until it reaches a temperature almost twice as high.

This is the range of temperature in which carbon dioxide attacks solid carbon very actively, and as a consequence the carbon dioxide liberated by the flux carries off enough carbon to restore approximately the equilibrium set by the conditions of temperature and the relative strength of the reducing and oxidizing influences in that zone.

This not only constitutes a loss of solid carbon, but a loss of heat as well, since the reaction $CO_2 + C = 2CO$ represents an absorption of heat of $14750 - 2 \times 4375 = 6000$ B.t.u. per pound of carbon dissolved. The carbon dissolved would obviously be equal to that in the limestone from whence the CO_2 comes, if all the CO_2 of the flux were reduced to CO, and as carbon constitutes 12 per cent of pure limestone (13.8 per cent of pure dolomite) and as the ratio of CO to CO_2 to which it is reduced is approximately 2:1 or two-thirds CO, we can see that 8 per cent to 9 per cent of the weight of the flux is the quantity of carbon dissolved and carried out the top of the furnace by the CO_2 of the flux. In proof of this fact gas samples taken from a point well below the stock line show a higher content of CO_2 than simultaneous samples from the furnace top showing that the CO_2 evolved by the flux was actually reduced to CO. I believe that this experiment has been made quite frequently, and I myself have made it with results which left no room for doubt.

The obvious suggestion is that the flux should be "burned" so as to drive off its CO_2 before charging into the furnace, and this has in fact often been proposed, but has never been done to any great extent. This failure may be due to inertia and the desire to avoid any additional operation at the blast furnace, but it has a certain justification in that most furnaces have a considerable excess of heat in the shaft and the limestone can be calcined with this without burning any fuel for this purpose. In many, if not most, cases this results in ultimate economy in dollars and cents in spite of the fuel dissolved by the CO_2. We can discuss this subject better when dealing with heat balance of the furnace in the next chapter.

A third source of solution loss is the contact of the ore and fuel and the direct reduction which results according to the equation $Fe_2O_3 + C = 2FeO + CO$ and $Fe_2O_3 + 3C = 2Fe + 3CO$.

These reactions take place freely throughout a wide range of temperature as shown by Fig. 2, and therefore every point of direct contact between ore and fuel is a possible point of direct reduction and solution loss. It would appear at first sight that this was precisely what we wanted, but when we come to deal with the thermal equations we shall see that it results in a very real loss, and I shall endeavor to show that the increase in the number of points of contact between ore and fuel accounts for the increase in the fuel consumption of fur-

naces which has resulted when their burden has been changed so largely to fine ore.

The conditions which lead to solution losses by any or all three of these methods are important and worthy of careful study, even though the theoretical laws of ore reduction do not control the action of the furnace to anything like the extent believed by some.

The Action of Hydrogen and Volatile Hydrocarbons

All furnace fuels contain a certain amount of combustible hydrocarbonaceous matter not driven off when the fuels were produced, but volatile at the temperature of the blast furnace, and as these frequently if not always contain considerable quantities of hydrogen their effect on the composition of the top gases is greater than their absolute quantity would lead one to suppose.

The quantity of volatile combustible matter in anthracite and coke is ordinarily 2 or 3 per cent, although it may go higher than this in some cases.

No analyses of this volatile combustible matter in anthracite and coke are at hand, and in ordinary cases and for ordinary purposes their quantity is not sufficient to exert an important influence. But in charcoal the case is very different; the volatile matter is about 30 per cent of the total weight of the fuel, and by far the larger proportion of it is combustible, about 50 per cent by volume hydrogen and about 15 to 20 per cent are methane or other hydrocarbon containing the same amount of carbon and hydrogen as that amount of methane in addition to some 10 or 15 per cent CO.

This is very important because the first two of these gases are extremely active reducing agents even at quite low temperatures, and the quantity of oxygen required to satisfy them is much greater than is required for CO or carbon. Hydrogen requires eight times its own weight of oxygen to convert it to water, and methane to convert it to water and CO_2 requires four times its weight of oxygen, as compared with one and a third times its weight to convert carbon to CO or two and two-thirds to convert it to CO_2. Moreover, about 30 per cent of the product of combustion of methane and all that of hydrogen is water vapor which mingles with the water vapor from the stock and completely disappears as a determinable quantity in the top gases.

Hydrogen is active as a reducing agent at temperatures lower than those required for much activity by carbon monoxide, and therefore the presence of this gas may be very beneficial in certain special cases. We have, unfortunately, no such reliable investigations of the reducing action of hydrogen as those of Baur and Glaessner for the oxides of carbon, but it is well known that the reaction is reversible; steam passed through a red-hot iron pipe is broken up, the oxygen attacking the iron of the pipe and hydrogen being set free. On the other hand, hydrogen will reduce iron oxide to metallic iron at quite a low temperature. But no data exist as far as known to me on the equilibrium percentages of hydrogen and water vapor at different temperatures in the presence of iron and carbon and their oxides.

The reversibility of the action of hydrogen will appear very strikingly in the next chapter; it will be seen that a chemical balance for the ingoing and outcoming materials of a charcoal furnace cannot be made unless the very considerable proportion of the total oxygen which disappears by combination with hydrogen be brought into account, while in coke furnaces it will be seen that hydrogen is produced by the decomposition of water, not only in the hearth of the furnace but also on a much more extensive scale in the shaft.

The reactions which are probably responsible for this result are

$$H_2O + Fe \rightleftarrows FeO + H_2$$

and

$$H_2O + CO \rightleftarrows CO_2 + H_2$$

both of which are reversible, as indicated.

The second is the typical reaction of the steam-blown gas producer.

The factors which control the direction in which these reactions take place are probably temperature and concentration of CO_2, but the indications are that temperature is the more important because hydrogen is consumed in the charcoal furnace, with its low top temperature, in spite of fairly high concentration of CO_2, while it is produced in the coke furnace, with its much higher top temperature, in spite of the low concentration of CO_2.

There is, however, much more ore and, therefore, more oxygen in proportion to the top gas in the charcoal furnace, and this may account for the oxidation of the hydrogen in that case.

These are some of the factors which affect the situation, but the conditions which control we frankly do not know.

The Carburization of the Iron

This is a subject of the details of which we know relatively little. Iron absorbs carbon eagerly up to between 1 and 2 per cent in the solid condition if exposed for a sufficient length of time at a high temperature, and in the liquid condition reasonable exposure to incandescent carbon will raise the latter element to about 2½ per cent in a neutral or slightly oxidizing atmosphere, but it is difficult to raise the carbon contents of a bath of steel beyond this limit by any means commonly available. Even in the electric furnace difficulty has been found in commercial operation in raising the carbon to the range which is commonly found in pig iron.

The explanation for this probably is that the conditions of exposure in the blast furnace are exceedingly favorable. The iron sponge, produced by the breaking up of the iron ore into powder under the action of the reducing gases and the removal of the oxygen from this powder, probably absorbs some carbon from the gas or the fine carbon precipitated from the gas before it reaches the zone of fusion, but not much is known about this.

After fusion the iron forms into drops presumably on the surface of the pieces of coke and then trickles down through the coke which constitutes the only solid contents of the bosh and hearth.

The progress of the iron is probably very slow at first, because until it is carbonized its temperature of fusion is that of steel, several hundred degrees higher than that of cast iron, while the temperature of the upper part of the bosh is much lower than that around the tuyeres. It may even be that the iron descends through the upper part of the bosh in the solid condition attached to the coke and is carried down by the latter in the solid condition. Then as it becomes more thoroughly carbonized and the temperature rises, it melts and completes the journey by trickling, but even this constitutes a slow descent because the surface of the coke is always porous and therefore rough, and the pieces of coke being in close contact with one another the path of the trickling iron is rough and tortuous.

Another important factor in retarding the progress of the iron and giving a chance for carburization is the high velocity of the gas upward, which must act to some extent like the up-blast through a shot tower in retarding the velocity of the liquid metal downward.

The conditions controlling carburization are not by any means thoroughly understood, and it is a lamentable fact that so little reliable work on the determination of carbon in cast iron has been done that our knowledge of the quantity of carbon in different irons made under different conditions is much less comprehensive than that of any other branch of the chemistry of iron.

We do know, however, that by the use of extremely high temperatures in the experimental electric furnace Moissan and more lately Witorff have succeeded in producing compounds of iron and carbon higher in the latter element than have ever been produced industrially. The compound Fe_2C seems to have been definitely identified as one of these products, and this contains 9.7 per cent of carbon. It is, therefore, probably safe to say that the higher the temperature, other things being equal, the more carbon will be absorbed. It is also probably safe to say that the more carbon in the hearth per unit of iron produced, other things being equal, the greater will be the carbon absorption.

The amount of excess heat in the hearth is probably a factor of much importance, and the nature of the fuel used may be of predominating importance since with charcoal fuel the carbons in the iron produced under certain circumstances rise to 4.50 per cent or more, although the temperature in the hearth is low relatively to that of a coke furnace which produces iron commonly running about 3.70 to 4.10 per cent carbon.

This subject will be further discussed in dealing with furnace operation and the quality of iron.

Manchester Meeting of the Society of Chemical Industry

The annual meeting of the Society of Chemical Industry was held in Manchester from July 14 to 16. According to the report of the Council, read by the secretary, Mr. C. G. Cresswell, the number of members is 4017.

There were less social functions than in former years, but more papers, mostly concerning the conditions and prospects of the British chemical industry and its relation to the chemical profession.

Presidential Address

Prof. G. G. HENDERSON, in his presidential address, said: "Since the outbreak of the war there has been much discussion concerning the present position and the future prospects of the chemical industries of this country, and I earnestly hope that the serious consideration which has been given to the subject will have at least one result—that we shall refrain from talk and proceed to action. We have been made to realize more clearly than ever before that during the last forty years chemical industry in Germany has made marvellous strides in advance, while in this country [England] it has by comparison stood still or even gone back. We have to admit that certain branches of applied chemistry, particularly the manufacture of dyestuffs, of synthetic drugs, and of organic compounds and fine chemicals in general have passed almost wholly out of our hands, or rather have never been taken up to any notable extent in this country. We cannot deny that the Germans have with energy and success developed on the industrial scale many scientific discoveries, such, for instance, as the various methods for the fixation of atmospheric nitrogen, while we have done little or nothing in that direction. Even our former supremacy in the manufacture of heavy chemicals has been seriously attacked. These are the facts."

Professor Henderson thinks there are two main causes of British lack of progress. "Firstly, we have failed to realize that 'scientific research work carried out in the laboratory, is the soul of industrial prosperity'—that modern chemical industry must of necessity be based upon research if it is to meet with success. This axiom may indeed have been tacitly accepted, but, speaking generally, it has not to a sufficient extent been made a guiding principle in our chemical industries. In the second place, there has not been in the past a sufficiently close and intimate interchange of information and opinions between manufacturers and professors of chemistry; in fact, most unfortunately for both manufacturer and teacher, the attitude has rather been one of mutual aloofness and reserve."

To rectify these errors Professor Henderson advocates the scheme of Industrial Fellowships, more or less on the lines of that successfully inaugurated by the late Kennedy Duncan in connection with the Universities of Kansas and Pittsburgh. "The essence of this eminently practical idea is that any manufacturer who desires to have some technical matter investigated applies to the chemistry department of a university or technical college for the service of a chemist qualified to prosecute research, and undertakes to provide adequate remuneration for a period of one or more years; the work is done in the chemistry department under the general superintendence of the professor, and, if necessary, facilities for large scale experiments are provided by the manufacturers."

As to the training of chemists for technical posts, Professor Henderson points out that opinions differ but may be grouped into three categories. "Some teachers appear unwilling to admit the possibility of the existence of the chemical engineer, and maintain that the chemical student requires nothing more than a sound scientific training to fit him for an industrial career, and that, if only he is a good chemist, he will be able after he enters a chemical factory to grapple with and overcome the special problems involved in the design and construction of apparatus and plant for chemical operations in any case. Others, again, hold that in addition to a thorough scientific training the student should receive such a course of instruction in chemical engineering as can be given in any teaching institution properly staffed and equipped for that purpose. Lastly, a few teachers apparently incline to the opinion that the student after acquiring a comparatively elementary knowledge of general chemistry should proceed at once to specialize in some branch of chemical technology."

This last method Professor Henderson considers to be wrong in principle and futile as regards results: any specialization in chemistry should be post-graduate work. The other two rival methods of training stand upon a different footing, and each can be defended by cogent arguments, but Professor Henderson's own experience leads him to advocate the second course.

Co-partnership in Chemical Industries

In a paper on this subject by Sir WILLIAM LEVER, it is pointed out that the present war has given Great Britain an awakening. British industries will be stimulated to organize efficiency as a result of the war. Yet the attainment of efficiency in mechanical appliances, in chemical knowledge, in banking arrangements, is not sufficient, but the human element must be taken care of. For this reason the author recommends co-partnership in the chemical industries—not simply profit-sharing, but also loss-sharing.

"Just as it is found in practice that the debenture holder, and to almost an equal extent the preference shareholder, take little or no interest in the undertaking in which their capital is invested, so it is found that the sole impulse and inspiration for development, growth, and activity in industries springs from direct interest in the results as represented by the holding of ordinary shares with possible profits or losses. When the board of directors are simultaneously ordinary shareholders, the greatest amount of efficiency, development and activity can be attained. The very fact that management and labor are often relegated solely to the position of debenture holder has reduced the efficiency

of management and labor and their interest in the undertaking in which they are engaged to the level of that of debenture holder, which, as we all know from experience, is, practically, a minus quantity." . . .

"I know of no industry to which the system of co-partnership applies with greater force than to the chemical industry. A British chemical industry, founded upon the principles of co-partnership, with employees trained and instructed as to what these co-partnership principles meant, and realizing the opportunities co-partnership offered them, would surely possess employees superior to those of competitors in Germany, or elsewhere, under mere wage and salary conditions."

It is more difficult in the chemical industry than in any other industry to assess the services of each member of the staff, whether as inventor, developer of the inventions of others, or organizer, or rank and file employee carrying on the routine process of production.

The following rules on co-partnership should be always kept in mind:

Profit sharing or co-partnership must not degenerate into charity or philanthropy. Its objects must be the increased success of the undertaking, with increased prosperity for all connected with it. It must not place management in the position of servant to labor through liability to criticism and censure. It must ensure to labor freedom from interference of management in the enjoyment of the benefits derived from profit sharing. It must possess greater stability than a mere system of bonus cash payment. Its benefits must be felt by the wives. It must have a distinctly elevating tendency on management and labor, raising them in the social and intellectual scale, and increasing their power for enjoyment and happiness as well as their power of usefulness. Control must remain with those who find the cash capital.

The whole basis of profit sharing or co-partnership cannot be other than enlightened self-interest for both capital and labor. Any other idea would be destructive to the self-respect of the employee, and lead to confusion from the point of view of capital. Philanthropy is own sister to charity, and charity is the mother of pauperism. There is no room for philanthropy in business, there is no room for maudlin sentiment; but there is ample room for a better and improved industrial relationship between capital and labor, one in which labor can become, equally with capital, interested in the results of the undertaking.

Research and Chemical Industry

Dr. M. O. Forster in a paper on this subject deplored the chasm between college and factory and pointed out that this estrangement proceeds in a vicious cycle. "If the manufacturer is not disposed to employ chemists on his premises, he could at least provide them with raw material or with problems which, if successfully handled and solved, would not only help him, but would give the instructors in that college the scent for technical inquiries. This would provide the first requirement in a course of genuine technology, a stimulus, and I am convinced that scores of chemists have been lost to industry from the absence of this connecting link. The young demonstrator, anxious and willing to work at anything useful, would be thrilled and exhilarated by a kilogram of waste material from Messrs. X and Y's manufacturing process, and a request to ascertain whether any valuable constituent was being thrown away; his mind would be directed forthwith into that particular field of industry, and whatever he found, even if it amounted to nothing, he would insensibly become potentially more useful to Messrs. X and Y, so that if these gentlemen ever did summon up courage to employ a chemist he, or the post-graduate student who had helped him, would be a suitable man to engage."

Dr. Forster said the first necessity for a closer union between research and industry is the development of a healthy public opinion on the subject of acquiring knowledge in general, scientific knowledge in particular, and more important than either, because it covers both, national wisdom. "In order to do this, speaking bluntly, our governments must advertise scientific methods of business and education by the employment of such methods in their own operations. In the establishment of such public opinion an important place should be given to the work which chemists do, the part which chemistry has played in the national economy, and the possibilities offered by a wider application of chemistry to industry, in order to attract to our ranks that type of young man which is able to use a chemical training as a weapon for making chemistry pay.

"Next, although many enlightened manufacturers already make good use of chemistry, their numbers must be increased, and the newcomers must not be too quickly discouraged by what may seem initially an unprofitable investment. It is not to be expected that when the war is over there will be any mitigation of Gottstrafe British Dyes, Ltd., and any other industry which ventures to raise its head, and the situation must be faced with resolute courage and all the resources of our people, both material and intellectual.

"In the next place, by some process which I cannot clearly foresee, but which must inevitably depend upon sympathetic pharmaceutical agreement, a means must be found by which the respective activities of chemistry and pharmacy may be differentiated in the public mind, so that existing vague ideas on this matter may be clarified. Concurrently with the removal of these motes from the eyes of other people, we must pay attention to the beam or two in our own. If the operation is carried out cheerfully, courageously, and conscientiously, our scientific descendants may have to bless this era as one of chemical regeneration, even if they do curse the ill-wind which wafted it to this country."

Finally Dr. Forster suggested the formation of a chemical intelligence department by the Board of Trade for the collection, tabulation, classification and distribution of chemical information, presentation of new problems, etc.

Development and Control of Industry by Public Influence

Prof. Henry E. Armstrong, in a paper on the subject, said: "The one chief lesson of this terrible war is the need of bringing home 'the idea of science' to the public at large; experts they can never be, but some respect for it they can acquire, and to insist that it be used regularly and systematically in the service of the country. It is clearly our duty to persist in urging its infinite value.

"All this by way of introduction—just to make clear my one thesis: that charity begins at home; that this body needs to wake chemical industry. Almost supine hitherto, you have allowed others to tinker with matters which primarily should be your concern."

Union is strength—is the motto of engineers. Medical men occupy a similar position; lawyers also; both professions are organized on trade-union lines. "But those who rate themselves scientific—the academic party as a whole—are an unorganized rabble, so individualistic, self-centered and unsympathetic that what is one man's meat is almost necessarily another man's poison. This is both our strength and our weakness, but we shall never win through until we can combine strength with

weakness. The lesson of the moment, the lesson a lifetime has taught me, is that chemists, too, must become professionals, and like others sell their services, not give them. We have not yet learned the lesson of the world; that people only appreciate that which they pay for; that the value of a thing is not appreciated until it has been sold freely. Academic chemists ought not merely to be allowed and encouraged, but almost required to work for payment, as consultants, like the engineers. The professor pure and simple should disappear." . . .

"One main reason why we are so much behind in some of the chemical industries is that the instruction given in our schools has been far too academic in character. It cannot be said too definitely, either too loudly or too widely, that chemistry has not attracted gentlemen—men of general mind, good presence, and real ability—in sufficient numbers into its ranks during many years past. We want much of the material that now degenerates into briefless barristers. Such material properly trained would be of worth, and command good pay."

Professor Armstrong criticized the work done by various committees appointed during the last year in Great Britain. The primary mistake was in appointing lawyers to controlling positions on these committees. Such men, however able and eminent, cannot have any real expert feeling on technical problems outside their own profession, and where there is no expert feeling, no proper sense of "technical effect"—to use Faraday's expression—there can be no "proportionate judgment" exercised.

"We have to bear in mind that the success of German chemical industry is due to two causes: Firstly, to the fact that the German universities are practical institutions—not collocations of compiling colleges—properly supported by the state and in touch with the educated community. The idea of science is abroad in Germany, though 'science' is not more taught in the schools than it is here. Science, however, is respected, and has acquired a money value in public eyes because it has been made real; the company promoter has been kept in subordination, and it has been shown that trust can be placed in those who undertake scientific ventures. . . . The second and true cause of German success is that the factories are in the hands of experts; moreover and especially ample provision is made for carrying out all necessary and desirable research work within the factories in well-formed laboratories, this being possible because a supply of properly trained men is to be had from the universities."

Professor Armstrong recommends that the government should levy an "insurance tax" on all industries in which the maintenance of research department is necessary and to apply the income from the tax to furthering research work.

"*Our plain duty in this society is to organize ourselves and when we are organized to claim the right to guide the government.* But unless the representatives of science subordinate their individualism, sink their differences and form a complete coalition of their forces, no public impression will be made. The task before us is indeed colossal. Before the war, Germany had control of the Russian market. It will be long before she will regain this, and here will be our opportunity—if our schools take Latin and Greek plays out of their bill and stage Russian instead, and if they add Spanish, we may have some chance in South America also, if meanwhile the Americans do not seal the market against us. The competition we shall have to meet outside Europe, especially in the East, will be greatly intensified, because this will be the chief market open to Germans. I have seen enough recently of German organization of trade in the East to realize that ours did not compare with it in efficiency."

Research in Technology

Dr. CHARLES C. CARPENTER, in a paper on this subject, emphasized that the chemical industry of to-day cannot make progress without research.

"That research must commence with the chemist goes without saying. Circumstances have, however, changed since the inception of the first great chemical processes. The technical demands made by modern manufacturers are much more extensive and exacting, and sole reliance upon the chemist would be fatal to the realization of success. Sooner or later the aid of the technologist must be called in. His equipment for the task is on a very different footing from that of his confrere, for it must be carried out on the large or working scale. Now surely here is an overwhelming case for localized centralization if one fact, and one fact only, is borne in mind. It is not from or among themselves that the greatest competition is to be feared, but from producers over the seas already organized. Let, then, every special industry build up its own schools or institutes of technology, not only to provide training for workers, but so fully equipped with resources that problems of all kinds can be submitted to them for research.

"It may be said that one manufacturer would be contributing to progress made by another. That may be true, but it would be better for him to put a small tax upon his profits for such a purpose than, by want of united effort, risk losing his trade altogether. It may be argued that the risk would be a great one in reposing so much confidence with the principals of such organizations. But if we distrusted our physicians we should run the risk of being decimated by disease. Is there one in a thousand who does distrust his adviser in sickness? Why should the physicians of industry be less honorable or disloyal? Such institutions as suggested would be clearing-houses for troubles to which manufacturers would automatically turn, whether perfecting an old process or working out a new.

"If as a nation we are to emerge successfully from the industrial battle which is awaiting us, we must pool not only our difficulties but their solution. When it is required to start new processes or adaptations, it will never do for each manufacturer to proceed as is now the case, viz., start *de novo* and work out for himself methods of its industrial application which are already known and used in other directions. He would get it from the institutes. If, as in some cases, the information as to certain methods of plant were confidential, he would be put into communication with the users, and matters might then be left to develop on ordinary business lines."

Chemical Engineering

Dr. G. T. BEILBY, in his paper on this subject, said that engineering has always had a definite place in chemical manufacturing, but the degree and kind of engineering skill which has found a place in the older chemical works has been frequently not of a very high order.

"One of the special features of large-scale chemical apparatus is the heavy depreciation to which it is subject and the need, therefore, for continual renewals and repairs. The skilled engineer who has been accustomed to the construction of high-class prime movers or mill machinery may be very ill-fitted to design and keep in repair the short-lived apparatus of the chemical works. A more adaptable but rougher type man is required, and these needs have produced a rather special kind of man, the 'chemical works engineer,' rather than the 'chemical

engineer.' If these facts are kept in mind we shall not find it at all surprising that a chemical works plant, especially in the older works, often has an improvised appearance which suggests either that the engineer in charge is actually slovenly or that he knows so well the temporary character of the work that he does not think it worth while to conform to the ordinary decencies of engineering design and construction! Tumble-down apparatus in only too apt to react on the processes which are carried on in it, and slipshod working is the outcome. The moral effect of rapid destruction of plant is certainly bad; hence the enlightened manufacturer is willing to make many sacrifices to secure more enduring forms of plant.

"Apart from the special characters which are due to the necessity for frequent renewal, there is no doubt that the influence of the chemist has had a definite effect on the design of chemical plant. A former colleague of my own, who had himself made splendid contributions to the improvements of the apparatus used in one particular industry, could find no more contemptuous way of expressing his opinion of any piece of apparatus of which he did not approve than to call it a 'chemist's job.' Of course, the chemist did sometimes get back on the engineer, if an elaborately designed piece of apparatus failed to give satisfactory results from a process point of view! In this case, unfortunately, any attempt at a *tu quoque* was more than ordinarily ineffective, as an 'engineer's job' was just the kind of job the constructor desired to make! It is not easy to define or characterize these two kinds of job by any simple definition. Chemists' apparatus is more the result of opportunism than of deliberately thought-out design. Contingencies are provided for as they arise, and initial mistakes in design are apt to be met in a partial or temporary way.

"The origin of the chemists' type of apparatus is found in the chemical laboratory, where it has generally been the aim of the professor to develop in his students a certain kind of individual resourcefulness. When the chemist needs to increase the scale of his apparatus, he naturally follows the type of construction to which he is accustomed, and even when the increased scale gets beyond the resources of the blowpipe table and the cork drawer, his ideas flow along the old laboratory lines. When the increase in scale is so considerable that it becomes necessary to call in the help of the engineer and his craftsmen, the designs proposed by the chemist still show their laboratory origin. The quick adaptability of the plumber's methods attract him rather than the engineer's carefully arranged series of steps from the drawing office through the pattern shop, the molding shed, and the foundry, to the machine shop. In pioneering work a 'chemist's job' is often the most suitable to use, but when the stage of steady manufacturing has been reached, all the resources of the drawing office and workshops should be devoted to the design and construction of suitable apparatus."

The procedure in the design of new apparatus in modern chemical works where sound engineering principle are allowed their proper might, is sketched by the author.

"In the modern organization there is room for the research chemist of high and wide attainments, for the scientifically trained engineer, also of wide attainments, and for a type of professionally trained man who is the natural medium of interchange between these two specialists. This intermediary is the chemical engineer. He must be a man of special aptitudes inasmuch as *he must have grasped the chemist's point of view as well as the engineer's.* The chemist thinks and works in terms of atoms and molecules and the laws which govern their combination. The engineer thinks of matter in masses which can be molded to his will by the craftsman, or of mechanical or electrical energy which can be generated, controlled and measured by machinery. The chemist is the master and director of his own operations, which he can, for the most part, carry out with his own hands. The engineer loses his direct hold on his operations whenever his ideas have been fully committed to paper in the drawing office. It is his special function to organize the labors of many workers.

"A certain number of men are able to enter fully into the spirit which actuates both types of expert, the chemist and the engineer; they can resist the particular exclusiveness of each, while giving to each its due weight. These are the naturally gifted chemical engineers who in one sense are 'born, not made.' In our colleges and universities the best that we can do for men of this gifted type is to give them the best possible opportunities for an all-round development of their powers. For the average men, we ought to provide a properly organized course of training in theoretical and practical chemistry, physics and mechanics, on professional, not on purely academic, lines.

"Our colleges have thus two distinct functions to perform, and it is best that this should be clearly recognized, first to allow the future leaders in applied science to come naturally to the top during their training, and second, to prepare a large number of well-trained professional men for the organization and development of industry. The ideal for these men must be a professional one. It is to be feared that the making of practical chemists has suffered severely from a fallacy—namely, that all students ought to aim at being pioneers in some branch of their science. Science and industry alike call aloud for *real pioneers,* for without these the highest type of progress cannot be realized. This call, however, cannot be met by the premature stimulation of 'originality' in men of very ordinary endowment. The effect of this stimulation is not merely futile, it is positively mischievous, for it raises an ideal which for the ordinary man is quite inappropriate during his preparation for a life of serious practical endeavor. In conclusion, I must repeat the statement of my belief that the phenomenal development of chemical industry in Germany has resulted much more from the large command of chemists and engineers of sound professional training and ability than from the possession also of an even larger supply of research chemists of mediocre ability."

A general program of the engineering society conventions and International Engineering Congress, to be held in San Francisco, Sept. 16-25, 1915, has been issued for the information of those expecting to attend. A copy may be had on application to W. A. Cattell, Secy., 417 Foxcroft Bldg., San Francisco. The program covers in outline the conventions of four of the national engineering societies, the meetings of the Congress, and the excursions planned.

The production of bauxite and the consumption of aluminium in the United States in 1914 were the largest ever recorded, according to the U. S. Geological Survey. The output of bauxite was 219,318 long tons, valued at $1,069,194, as compared with 210,241 long tons valued at $997,698 in 1913. The principal producing States were Alabama, Arkansas, Georgia and Tennessee. Arkansas produced more than 80 per cent of the output. The principal uses for bauxite are the production of aluminium, aluminium salts, bauxite bricks and such artificial abrasives as alundum. The quantity of aluminium consumed in the United States in 1914 was 79,129,000 lb., against 72,379,000 lb. in 1913. In 1884 the production was but 150 lb. The consumption of the metal is constantly expanding.

Industrial Energy as a Military Weapon*

BY J. R. FINLAY

At the beginning of the present European war I had believed that industrial energy would prove to be the decisive factor in this present struggle, and that this energy might be fairly represented by the use and production of coal and steel. Part of this proposition is now recognized by the public; the other part is not. It is now seen that the nations of Continental Europe that are facing Germany, namely, France, Russia and Italy, are no match for Germany in the production of the necessary equipment and munitions for fighting. I argue that it is equally probable that the whole combination of the Allies, including England, is deficient in the capacity for organizing and for utilizing equipment. I am disposed to believe that the second element is more important than the first, because it requires time to develop. You will understand that I am working on the supposition that military success arises from the same kind of development as industrial success. It will take some time longer to prove this.

The idea is abroad that Germany may be conquered by the Allies if the latter will buy enough copper and other munitions. The reality is that the buying of supplies is a comparatively insignificant part of the problem. To take an industrial comparison, let us suppose that the plants of the United States Steel Corporation were supplied, complete, to Russia, without the organization as it exists to-day. What use could Russia make of them?

I do not mean to imply that the individual Russian is necessarily inferior as a workman, or as a man, to the individual American. That is one of the difficulties in understanding this present situation. Each of the great nations and races of mankind is able to furnish human material that can compete on even terms with that of any other nation. But I think you will recognize quickly that it would take the Russians many years to make any adequate use of the plants of the United States Steel Corporation. It is hardly worth while to go into details. The operation of those plants. including mines, steamships, railroads, rolling mills and factories of all kinds, requires the development of a vast amount of specialized labor; it also requires a great deal more than that, namely, a slowly developed and highly organized control. The plans and the execution of them must be tested by competition with rivals. The organization must know the fields in which the products, when made, can be sold and utilized. It would be easy to dwell on this subject a long time, but I think you will soon conclude that the plants of the United States Steel Corporation would never reach anything like the effectiveness in Russia which they have in this country, until the Russian nation is developed industrially to such an extent that it can meet such an organization on even terms. In other words, other industries, all of the industries in the country, in fact, would have to be developed in a substantially equivalent manner. This certainly cannot be accomplished over night, nor during the probable continuance of any war. It is a matter that requires nothing short of the industrial organization and development of the nation. A generation, or even two generations, is a short time for such an accomplishment.

Dropping this subject for a moment, it seems to me that we should stop and discuss fundamentals a little.

One such fundamental is that our political ideas and most of our beliefs and prejudices date from the time when the steam engine was unknown. I believe that economic changes have taken place in the leading civilized nations without producing, as yet, the inevitable change in political and social ideas. We are facing facts which we do not recognize, or at least, which are not recognized by the public. We go through forms of thought and attach ourselves to certain prejudices that will not stand the analysis of modern actualities. Some of our political sentiments are like the buttons on a dress coat, which were put there originally to attach swords to, because gentlemen wore swords, and the dress coat is the coat of a gentleman; but there is no longer any actuality in the sword as a weapon, either social or military. The fact that we like to see buttons on a dress coat is a mere sentiment which does not change in the least the relative efficiency of the sword and its successor, the revolver.

What changes of a political, social and religious nature are to take place I do not know. One thing that the world is learning beyond doubt, is that individual effort, no matter how well developed the individual, is no longer a match for corporate effort. This is a lesson that the Frenchman and the Russian must be learning. We in the United States have learned it, but we hardly realize that we have learned it.

Let me try to explain what I mean. There are certain efforts that cannot be accomplished by the individual that require a combination of people such as was not contemplated at the time when our government was established. We can see plenty of examples in the mining industry and plenty more in the railroad business. In fact, we all know that the business of our country in general has reached a point where the large corporation is absolutely indispensable. Consider, for instance, the Utah Copper Company. Nothing but failure of such an undertaking could possibly have rewarded the efforts of any man or any group of men in this country 100 years, or even 20 years ago. Look at the organizations required to conduct the railroad business of this country. The railroads all started in a more or less individualistic manner. A little railroad was built from New York to Harlem; another from Harlem to Poughkeepsie; a third from Poughkeepsie to Albany; a dozen pieces of railroad were constructed to form a patchwork system of travel between New York and Chicago. The progress of our industry soon made it plain that such a system was absurdly less efficient than it might be; consequently these little roads were thrown into one system, and operated by one head, so that freight and passengers could be carried through with less expense and delay.

My belief is that the fundamental desire of the human race is to secure greater economy in the production of the necessities and luxuries of life. Any political system or any social idea which interferes with that economy will go to the wall, will be defeated and discarded. The demand for efficiency will finally triumph over any preconceived prejudices regarding personal and political liberty.

We were all born while a revolution was going on in human affairs, and we shall die before that revolution ends. This revolution is a fundamental accomplishment, such as the human race is not likely to repeat again for thousands of years. It is something that we are all familiar with, but which we do not think very much

*A paper read before the Mining and Metallurgical Society of America. In the informal introduction to his paper, which is published in full with the discussion that followed, in Bulletin 86 (Vol. 8, No. 7) of the Society, Mr. Finlay said: "I think the result of this war will be to arouse the entire world to the importance of the evolution through which we are going. We do not know the military situation in Europe. The nations do not give away their military secrets, but I had an idea last September that the outcome of the war could be predicted by a consideration of other than military factors. The ideas I intend to convey are, frankly, speculative, but after ten months of war it looks as if some of them were probably correct. I have formed one idea, the correctness of which remains to be proved, and I intend to call your attention to it."

about. It is the conquest of natural energy by the human brain.

One hundred and fifty years ago men had no resources for accomplishing their work except the muscular power of men and animals, with a little crude development of wind and water power. Now we use our hands and our brains to direct forces scores of times more energetic. The result is prodigious and it is causing a complete rearrangement of our mode of life. It is causing us to look upon nature itself in a different way, and it is altering profoundly the relations between men and between nations.

The source of this power at present is largely coal. The power of coal is developed through machines made of metals. This is not so much a chemical or material fact, as it is a human fact. The utilization of this power is made possible only by the development of human organizations to match it. A locomotive is no more the machine that accomplishes the work of a railroad than a statue is a living man. You cannot use a locomotive without a railroad, and you cannot have a railroad without work for it to do; you cannot have work for it without big industries. In short, you cannot have first-class mechanical service and efficiency except in a highly developed industrial nation. The mere existence of power-driven industry on a large scale proves in itself that a country which supports it possesses a different and more efficient organization than a country which does not support it.

When I learned some years ago that it took 10 to 15 Hindoo coolies to accomplish the work of one of our miners in this country, I could not understand it. The difference seemed preposterously great. It was all the more extraordinary because it occurred in a mine equipped with machinery just as thoroughly as the mines of this country. The reasoning I have offered you is an attempt to explain it. Industrial efficiency cannot exist in a population that neither understands nor demands it.

An adequate explanation must cover the improvements that are steadily made in our business. I know of mines in which each man is producing twice as much as he produced 10 years ago, without working any harder, and without any improvements in or additions to the machinery. I am satisfied that industrial efficiency means nothing less than national effort, produced by slow growth, by the habit of co-operation, and by a widespread recognition of the value of co-operation and a belief in its value.

It is a fact not generally recognized that to-day there are only three nations in which mechanical industry is widespread, namely, the United States, the British Empire, and Germany. It is not fair, of course, to say that industry has not been developed in other countries, but those nations are so far ahead of any rivals that they are very distinctly in a class by themselves. These three nations produce about 90 per cent of the coal of the world, and undoubtedly operate 90 per cent of its machinery. It is a remarkable fact—it may be an accident, but still it is a fact—that all of these nations are predominantly Teutonic. It may be an accident that this race of men happened to gain possession of the more important territories that contained coal; but whether an accident or not, it makes no difference as to the importance of the developments that have come from it.

It happens that one of these nations is the most highly developed military nation in the world. The other two, while developed industrially quite as highly as Germany, happen to be about the least military nations of the world. In my judgment, the unmilitariness of England and the United States is due to one cause only, namely, their isolation, their freedom from enemies capable of easily attacking them. If these nations felt compelled to do so, they could develop enormous military powers; but we may also believe, from our available sources of reasoning, that the development of such military power will take a long time and can be accomplished only by a thorough political and social organization on terms of military efficiency.

This is a long introduction to the concrete facts in Table I to which I now wish to call your attention.

Table I.—Comparison of Industrial Energy as Represented in Iron and Steel Plants of Russia, United States, and Germany

Russian Iron and Steel Plants, 1911.	
Number of plants	255
Workmen (Poland, 17,304)	263,653
Output of pig-iron, tons	3,943,000
Output of ready iron, tons	2,912,000
United States: U. S. Steel Corporation, 1910.	
Output of pig-iron, tons	11,831,000
Output of ready iron, tons	10,733,000
Employees manufacturing	154,563
Employees mining, coking, and transportation	60,000
Output per man:	
Russia: ready iron, tons	11
Pig-iron, tons	14
U. S. Steel Corporation, (total labor) ready iron, tons	50
Pig-iron, tons	55
Per manufacturer, ready iron, tons	70
Pig-iron, tons	76
United States: Rolling Mills and Blast Furnaces, 1909.	
Output of pig-iron, tons	25,600,000
Men employed	304,000
Output per man, tons	84
Germany: 1910.	
Metal workers of all ages	589,649
Output of pig-iron, tons	15,000,000

(If 400,000 are in ironworks, the output is 37 tons per man, about what we should expect by comparison with U. S.)

Data as to the production and consumption of fuels in the various countries are not so easy to procure without careful investigation. I take it that the main criterion of a nation's industrial activity is its consumption of coal, or any other form of mechanical energy, rather than its mere output. We shall have to make several tables to express what I mean.

Table II.—Production of Coal and Petroleum on the Continent of Europe and Elsewhere in 1912.

France:	
Production, tons	44,000,000
Imports, tons	19,000,000
Consumption, tons	63,000,000
Russia:	
Production of coal, tons	31,752,000
Imports of coal	Not given
Production of petroleum, tons	9,247,000
(If we assume that one ton of petroleum is equal in efficiency to 1.5 tons of coal, we might credit Russia with a total fuel consumption of about 45,000,000 tons.)	
Belgium:	
Production, tons	25,322,000
Servia:	
Production, tons	335,000
Total production for this group, tons, about	115,000,000
Probable consumption, tons, about	135,000,000
British Isles:	
Production in Great Britain, tons	291,666,000
Exports, tons	95,536,000
Consumption, tons, about	196,000,000
Canada:	
Production, tons	15,000,000
Imports, tons, about	10,000,000
Consumption, tons	25,000,000
Australia:	
Production, tons	15,000,000
India:	
Production, tons	16,000,000
Total output of the British Empire, tons, approx.	338,000,000
Consumption of the British Empire, tons, approx.	225,000,000

Total industrial energy, represented by coal production among the Allies, not including Japan, at the beginning of the war, approximately 473,000,000 tons produced, and approximately 387,000,000 tons consumed.

Production of Germany and Austria-Hungary in 1912.

Germany:	
Production, tons	282,000,000
Net exports, tons	24,000,000
Consumption, tons	258,000,000
Austria-Hungary:	
Production of coal, tons	57,000,000
Imports of coal, tons	5,000,000
Production of petroleum, tons	1,000,000
(Equal to 1,500,000 tons of coal).	
Total production of Austria-Hungary, tons	63,000,000
Total output of Teutonic combination at the beginning of war, tons	340,000,000
Total consumption, tons	322,000,000

TABLE III.—RELATIVE PRODUCTION AVAILABLE WITHIN AND WITHOUT THE GERMAN LINES TO-DAY (USING FIGURES OF 1912)

For this purpose we will consider only the amounts consumed in the various countries, as representing their manufacturing energy.

Originally consumed in Germany and Austria-Hungary, tons	322,000,000
Add production of Belgium, tons	25,000,000
Add production of Northern France, tons	27,000,000
Add production of Western Poland, tons	6,000,000
Add production of Turkey, tons	1,000,000
Total manufacturing energy available, tons	381,000,000

The manufacturing energy probably available on the side of the Allies on the Continent, is as follows:

Russia, tons	40,000,000
France, tons	36,000,000
Italy, tons	12,000,000
Servia, tons	335,000
Total on the Continent, tons	88,335,000

The industrial energy of the British Empire remains about as it was, and is represented by approximately 250,000,000 tons of coal, which, however, is scattered all over the world. Thus it appears that while the Teutonic group began the war with a manufacturing energy equal to about four-fifths of that of all the Allies, excluding Italy, it now has a clear preponderance over the entire combination, including Italy.

We will similarly compare the situation with respect to the production of iron.

At the beginning of the war, Germany had a production, using as before the figures for 1912, of about 20,000,000 tons, to which she has added the production of Belgium, 2,500,000 tons and approximately 65 per cent of that of France, say, 3,500,000 tons, besides whatever may be produced in Poland; making a total manufacturing equipment available to-day of some 26 to 27 million long tons.

At the beginning of the war the Allies had the following production:

United Kingdom, tons	8,800,000
France, tons	5,000,000
Belgium, tons	2,500,000
Russia, tons	2,500,000
Canada, tons	1,000,000
Total, tons	19,800,000

At present the manufacturing ability of the group of Allies, as represented by pig iron, is probably not over 14,000,000 tons, even including Italy. Thus we see that at the beginning of the war the Germans possessed equipment for iron manufacture approximately equal to that of the Allies, but has now converted it into a preponderance of two to one.

It is interesting to know that the occupation of Belgium and Northern France deprived the Allies of industries consuming more than 50,000,000 tons of coal and producing more than 6,000,000 tons of pig iron a year. In the production of iron the facilities thus taken away from the Allies was equal to two-thirds of the entire production of Great Britain, and there is every reason to believe that this capacity was better adapted, on the whole, for the production of military supplies than the equipment in the British Isles.

The Germans have explained that their invasion of Belgium was a matter of military necessity. I have seen no statement as to what that military necessity was, but if this equipment is as important as we may now suppose it to be, we can make a pretty good guess. They probably felt that if they did not occupy this manufacturing district its output would certainly be used against them, if not by the actual military participation of Belgium, at least by furnishing munitions.

Some further interesting comparisons may be made. In the consumption of fuels, the United States is easily the foremost nation, consuming an average of over 5 tons per capita. England, Belgium and Germany seem to be about on the same level with the consumption of approximately 4 tons per capita.

It is, I believe, conceded by all observers that the industrial output per man is greater in the United States than in any other country; probably about in proportion to the consumption of coal, that is to say, the use of mechanical energy.

A review of the consumption of fuels by the leading industrial nations shows some interesting figures. Russia is apparently in about the same condition that the United States was in about 1850. Wood is still largely used as fuel for locomotives, just as it was in this country at that time. The consumption of mineral fuel is about ¼ ton per capita, as it was in the United States in 1850. In the progress of the United States from 1850 to 1914 we find that to-day we are using twenty times as much coal per capita as we were then; and an estimate of the wealth per capita, as given in the World's Almanac, shows $300 in 1850 and $1,350 in 1914. If the productivity of a nation can be measured by this wealth, it would seem that the producing capacity of an American citizen is at least four times that of a Russian.

It seems also that, by the same comparison, France is now only as far advanced industrially as the United States was about 1875. This certainly does not mean that specialized industries are not fully as well developed in France as in this country. What it probably does mean is that the mass energy is much less. France consumes only about 1.6 tons per capita, which I think almost certainly means that most of the French people are at work on farms and small shops and not in the factories. They work more with their hands and less with machinery.

The whole population within the German lines, excluding Turkey, is approximately 135,000,000; including Turkey, about 155,000,000. The average productivity of this whole mass of people, as measured in coal and iron, is about equal to that of the United States in the year 1890. Coal consumption is 2.5 tons per capita.

In white population the Allies stand about as follows:

British Empire	60,000,000
France	35,000,000
Italy	35,000,000
Servia	5,000,000
Russia	150,000,000
Total	285,000,000
Coal consumption, tons	340,000,000
Coal consumption, per capita, 1.2 tons.	

This average is equal to that of the United States at about 1870. Thus the Germanic combination is about twenty years ahead of the average of its opponents in the use of machinery. They draw their men and resources from a total area of 1,000,000 square miles, while their opponents come from the ends of the earth and dwell in an area of 10,000,000 to 15,000,000 square miles.

The newspapers and the public have arrived at the importance of these facts, so far as they apply to munitions of war. The cry is broadcast that the Allies must be supported by the manufacturing resources of England and the United States.

I return now to my original suggestion, that manufacturing power is only one-half of the problem. It seems likely that the organizing ability in Germany has attained a superiority over that of the Continental Allies in some proportion to her superiority in industrial activity.

To illustrate the situation in Europe, let us suppose that the States of the Union should get into war against one another. Suppose the States of Illinois, Indiana,

Michigan, Ohio, Pennsylvania, New York, Connecticut and New Jersey should form a combination to resist the rest of the United States, and Canada thrown in. Suppose for full measure we throw in Mexico and South America as opponents of this bit of territory. We would then have a population of 40,000,000 in a territory of 285,000 square miles fighting a population of 150,000,000 occupying a territory of 15,000,000 square miles. Which would be likely to win? I may be foolish, but it seems to me that the group of States between New York and Chicago would probably win decisively. Why? Because in that area, producing 75 per cent of the coal and making 87 per cent of the iron of the country, there is almost a monopoly of the organized manufacturing and engineering energy of the Western hemisphere. The area contains practically all the plants capable of manufacturing arms, munitions and special devices. In this territory we have not only the plants, but the trained population, the trained leaders and organizers. If we permit ourselves to imagine that this group of States were organized under one efficient corporation which had the control of every citizen for the purpose of carrying on war, we should have in America something like the situation in Germany to-day. We could well reject the idea that the New Yorker or the Pennsylvanian was in the least superior to the Canadian or the Texan, but that would not alter the fact that the superiority of our group of States in the production of munitions, the transportation of supplies, the organization of effective effort, and its ability to strike quickly, would be very great indeed. If this group of States should make as its first move the occupation of West Virginia and of Missouri, it would add to its preponderance much as the Germans have added to theirs by the occupation of Belgium and Poland.

If, in addition to the enemies we were fighting in America, Great Britain should come in and use her command of the seas to help our neighbors out with supplies, what would be the result? I do not believe that it would be decisive. I still think that the problem of conquering such a unit would be insoluble. We might not be able to make extensive conquests, nor wrest the command of the seas from the English, but we could meet any probable attack with such a wall of mechanical energy that we could make expectant conquerors sick with hopes deferred.

War Consumption of Metals

In the discussion which followed Mr. W. R. Ingalls discussed the extraordinary consumption of metals by the war which is much greater than had been anticipated by experts. At the beginning of the war the consumption of copper by the Allies was estimated as 100,000 metric tons a year; independently the consumption by the Germans was also estimated as 100,000 metric tons a year. Both estimates are conservative and probably too low. Considering that the world's largest production in any year was about 1,000,000 metric tons, we begin to have a better perspective of the military demand.

"Most of the copper is used in the form of brass, which, of course, requires a corresponding proportion of spelter. In purchasing the spelter for this brass an extraordinary effect upon the market was produced. Ordinary brands of spelter rose to about 500 per cent of normal value, while high-grade spelter realized prices approaching the price of tin in ordinary times. Attention was chiefly centered on the special brands of spelter produced by the New Jersey Zinc Company. This is a metal in a class by itself, containing upward of 99.9 per cent zinc, and being free from undesirable impurities to an extent that is unmatched by any other spelter. This spelter is sold as the Bertha and Horsehead brands. Before the war such spelter had a rather limited use for special purposes. Inventors and promoters were always going to duplicate it, and in prospectuses they were always going to get the 2 cent or 3 cent premiums that these brands normally realized above the price for prime western. Those of us who knew something of conditions warned all of our friends who wanted to go into such enterprises that the addition of any important supply of this kind of metal, even if it could be produced, would break the margin, and in figuring upon a new zinc-smelting enterprise it was never safe to reckon on anything higher than the price for prime western, or good ordinary brands. Recent events have been directly contrary to our *antebellum* opinion and advice. We have seen it impossible for buyers to obtain all of the high-grade spelter they wanted, whence the premium for such spelter rose phenomenally. Almost anything that the New Jersey Zinc Company wanted to ask it could get. Other smelters were left to make a spelter by redistillation, almost, but not quite, as good. Impure spelter may be refined into pure spelter by redistillation, just as pure water may be obtained from brine, but there is difficulty with respect to the cadmium content, which is volatile, like zinc, and perhaps some difficulty with respect to lead also; wherefore it appears to have been impossible to raise the spelter redistilled from prime western above 99.75 to 99.85 per cent of zinc, which makes it a high-class intermediate spelter, rather than high-grade spelter properly speaking, according to the official classification. However, such spelter has been greatly in demand and has commanded very high prices.

"Now just why the military buying has been so insistent upon these superior brands is something of a mystery to me. Of course, I know that such spelter has always been required for the manufacture of cartridge cases, and there are good reasons why it should be, but apparently manufacturers who have been going to make ammunition of other kinds than cartridge cases have also insisted upon such spelter. I have wondered whether the military experts have not, in some cases, specified a purity that is not really necessary, having in mind only the idea of obtaining the very best. I have not heard that the German military authorities have exhibited any such crazy demands for high-grade spelter. What have they been doing for their supply of it? Other things are curious. Why should it have been necessary to produce a condition of spelter selling for £110 per ton in London, while it is selling for £29 in Germany in 1000-ton lots?

"Lately we have witnessed, also, a spectacular demand for lead. This metal is used for the cartridge bullets, for the shrapnel balls, etc.

"Other metals have experienced similar advances, which non-military persons did not foresee. Antimony is one of them. This is used for hardening the lead for the several bullets. Quicksilver is used in making the fulminates which go into the caps. The quicksilver market has been especially disturbed since Italy entered the war and thus cut off the supplies that we were heretofore able to draw from it. Aluminium is used largely in the construction of aeroplanes and dirigibles. There are rarer metals which also have had sensational advances. Such a one is magnesium, which doubtless is required for making the illuminating bombs, flares, etc., used in night attacks."

Mr. G. C. Stone (N. J. Zinc. Co.) explained that cartridge brass has to stand the severest strains in drawing presses and the zinc should be free from cadmium and contain not over 0.05 per cent lead and 0.15 per cent iron.

Condensers for Evaporating Apparatus

Principles, Types, Tests

In our August issue we gave an extensive account of the chapter on vacuum pans from the recent publication of Professor **E. W. Kerr**, assisted by J. F. Gunther and W. A. Rolston, on Sugar House Heating and Evaporating Apparatus (Louisiana Bulletin No. 149, Agricultural Experiment Station of the Lousiana State University and A. & M. College, Baton Rouge, La.). This same bulletin contains a very interesting chapter on sugar-house condensers from which we take the following extracts. Professor Kerr first considers the general principles of condensers for evaporating apparatus, then describes different types of condensers and finally gives the results of tests made by him.

General Principles of Condensers for Evaporating Apparatus

As a general thing, 26 in. of vacuum referred to a barometer of 30 in. is sufficient for vacuum pans and evaporators of the submerged tube type.

Film evaporators can use higher vacuum to advantage because there is no loss of temperature fall in them due to hydrostatic head. The loss due to hydrostatic head is much greater in the last body of a multiple effect than in a first body, and for this reason a high vacuum in the submerged tube types does not result in the increase of capacity that is possible in film evaporators.

High vacuum is also more desirable in triple and quadruple effects, especially of the film type, than in double effects. The rate of evaporation per square foot of heating surface per hour must be limited in order to prevent entrainment. With a given total temperature fall a double effect will naturally have greater temperature falls in each body than in triples or quadruples, resulting in higher rates of evaporation. For this reason the increased total temperature fall due to increasing the vacuum or the steam pressure is less likely to cause entrainment in triples and quadruples than in doubles.

The cost of high vacuum, 27 or 28 in., is greater than for ordinary amounts of vacuum for several reasons, among which may be mentioned more cooling water, more vacuum pump capacity, greater attention to providing against leakage from stuffing boxes, etc., larger vapor pipes and larger condensers. Most sugar-house condensers are of the barometric jet type, in which the vapors mix directly with the cooling water, being condensed and cooled down to the temperature of the water leaving the condenser. The cooling water required per pound of vapor condensed can be calculated by means of the formula:

$$W = \frac{H - (t_2 - 32)}{t_2 - t_1},$$

in which H is the total heat of steam at the pressure corresponding to the vacuum, t_1 is the initial temperature of the cooling water and t_2 the final temperature of the cooling water. Increasing the vacuum will naturally increase the value of t_2, which in turn will result in increasing the weight of cooling water per pound of vapor condensed.

This increased amount of cooling water means larger and more costly cooling water pumps, also increased steam consumption, wear and tear. Table I shows the increased amount of cooling water required with high vacuum.

The values in Table I were calculated according to the above formula, the final temperature of the cooling water being assumed to be 5 deg. lower than that corresponding to the vacuum.

Inspection of the above formula shows that in order to secure a given vacuum with the least amount of cooling water the value of t_2—that is, the leg pipe temperature—must be a maximum. In other words, the condenser must be the main factor in forming vacuum and not the vacuum pump, the object of the latter being to remove air and not vapors.

TABLE I—COOLING WATER AND VACUUM

Vacuum	Cooling Water Per Lb. Vapor, Lbs.
24.0	18.8
24.5	20.0
25.0	21.3
25.5	23.2
26.0	26.4
26.5	29.4
27.0	35.6

The pressure in a condenser is the air pressure plus the vapor pressure. According to Dalton's law, "The pressure of a mixture of a gas and a vapor is the same as the sum of the pressures each would possess if it occupied the same space alone."

In a vessel containing vapor only, with a vacuum of 27.99 in. of mercury, the temperature is 100 deg. F. In case there is some air mixed with the vapor, however, the pressure (1.926 in. of mercury) would be the sum of the pressures due to the air and to the vapor, and the pressure due to the vapor would be something less than 1.926 in., and the temperature in the vessel would correspond to this lower pressure. From this it is evident that the less air there is in a condenser, the nearer will the temperature approach that corresponding to its pressure, as given in steam tables.

Even in the best of condensers, the temperature of the discharge water (hot well) is lower than that corresponding to the vacuum. This is due to the presence of air with the vapor and a vapor pressure less than that shown by the gage, the temperature being due to the vapor pressure. If it were possible to exclude the air entirely, the temperature would be that due to the pressure shown by the gage. This would result beneficially in increasing the temperature of the hot well, and this in turn would decrease the weight of cooling water required to condense a pound of steam.

When pure steam in a condenser is cooled by contact with air-free water the original volume occupied by the steam and water is greatly reduced. For example, assume that one pound of steam under a pressure corresponding to 26 in. of mercury requires 30 lb. of water at 70 deg. F. to condense it. The volume of the steam is 175 cu. ft. and that of the water about ½ cu. ft., a total of 175½ cu. ft. Upon condensing, the volume of 1 lb. of steam becomes 1/60 of a cu. ft., so that the final volume of the mixture will be ½ + 1/60 = 0.5016 cu. ft. Thus, the volume is reduced from 175.5 cu. ft. to 0.5016 cu. ft. by perfect condensation, and the resulting void would give practically a perfect vacuum.

However, in actual condensing apparatus the above conditions are not fully carried out for the reason that there is air both in the steam and in the cooling water entering the condenser. In addition to the air in the condensing chamber, which decreases the vacuum—that is, increases the absolute pressure—there is also vapor from the warm water, the pressure of which depends upon the temperature of the water. Even if there were no air in the condensing chamber this vapor would be present. The figures in Table II taken from a steam table show the water vapor pressures for varying temperatures under vacuum.

Column 3 of Table II is obtained by subtracting the vapor pressure, column 2, from the pressure of the atmosphere which is assumed to be 29.92 in. mercury. The values in this table apply to water vapor only. If

it were practicable, a removal of the vapor formed, as explained above, could be resorted to for the purpose of increasing the vacuum. By thus removing vapor from the condenser with a pump, other fresh vapor would be formed from the water in the condenser to take the place of that removed and the absorption of heat required for this would cool the water and this in turn would result in an increase of vacuum.

Table II—Water Vapor Pressures for Varying Temperatures Under Vacuum

Temp. of Water, Degrees F.	Vapor Pressure, Inches Mercury	Vacuum Inches Mercury
32	.1804	29.7396
40	.2477	29.6723
50	.3625	29.5575
60	.5220	29.398
70	.739	29.181
80	1.029	28.891
90	1.417	28.503
100	1.926	28.994
110	2.589	27.331
120	3.438	26.482
126	4.057	25.863
134	5.02	24.90
152	7.95	21.97
162	10.12	19.80
170	12.20	17.72
182	15.98	13.94
190	19.02	10.90
200	23.47	6.45
212	29.92	0.00

Owing to the great volume of this vapor, however, a pump sufficiently large for this purpose would be impossible, as is shown in the following example. Assuming a condenser which requires 30 lb. of water to condense 1 lb. of steam and that the water is heated in the condenser to a temperature of 126 deg. F., corresponding to a vacuum of 26 in., let us determine the volume of vapor that must be removed by a pump in order to reduce the temperature to, say, 116 deg.—that is, to reduce the temperature 10 deg.

For each pound of steam to be condensed there would be required 10 x 30 = 300 B.t.u. to cool the water 10 deg. The latent heat of evaporization of water at 26 in. being 1026 B.t.u. $\frac{300}{1026}$ = 0.292 lb. vapor would be formed, and, therefore, removed by the pump in order to cool the water 10 deg. One pound of the vapor at this temperature has a volume of 175 cu. ft. Therefore, 175 x 0.292 = 51 cu. ft. of vapor would have to be removed for each pound of steam entering the condenser. An evaporator with 5000 sq. ft. of heating surface in the last body would deliver, say, 30,000 lb. of vapor to the condenser per hour, or 500 lb. per minute. The pump displacement of vapor to reduce the temperature 10 deg. would, therefore, be 51 x 500 = 25,500 cu. ft. per minute. The vacuum corresponding to 116 deg. is 27 in.; 25,500 cu. ft. of vapor would thus have to be removed per minute to increase the vacuum only 1 in. This would require a pump with dimensions entirely without the limits of practicability.

Larger vapor pipes are required with high vacuum because the specific volume of vapors—that is, the volume in cubic feet—occupied by 1 lb. of vapor increases rapidly as the vacuum increases. For example: the specific volume of vapor at 26 in. of vacuum is 175 cu. ft., for 28 in., 330 cu. ft., and for 29 in., 638 cu. ft. Thus the area of vapor pipes for 28 in. vacuum needs to be nearly twice that for 26 in. vacuum. The work to be done by condensers for evaporators depends upon the number of bodies. A condenser for a quadruple effect would have to handle about half the vapors that one for a double of the same capacity would have to handle.

Types of Condensers

Condensers of the kind used in sugar-house work are nearly all of the barometric type—that is, the vapor and the water mix in direct contact. The mixture of condensed vapors and cooling water passes to the hot well through the leg pipes by gravity, the condenser being located some 34 ft. or more above the surface of the water in the hot well. These condensers require injection water pumps for elevating the water to the condensers; also, in most cases, vacuum pumps of the rotary dry type, or of the slow speed water sealed type.

Generally a sugar house condenser consists essentially of a tall cylindrical vessel into which the vapors and the cooling water are led and mixed. The water enters at the top and is sprayed as it falls and mixes with the vapors. These condensers, according to the manner in which the steam is introduced, may be classified as parallel-current and counter-current; in parallel-current condensers the vapor enters the top, the cooling water and the vapors flowing in parallel currents at the bottom and out through the leg pipe; in counter-current condensers the vapors enter at the bottom and pass upward, their direction of movement being counter to that of the cooling water, hence the term counter-current.

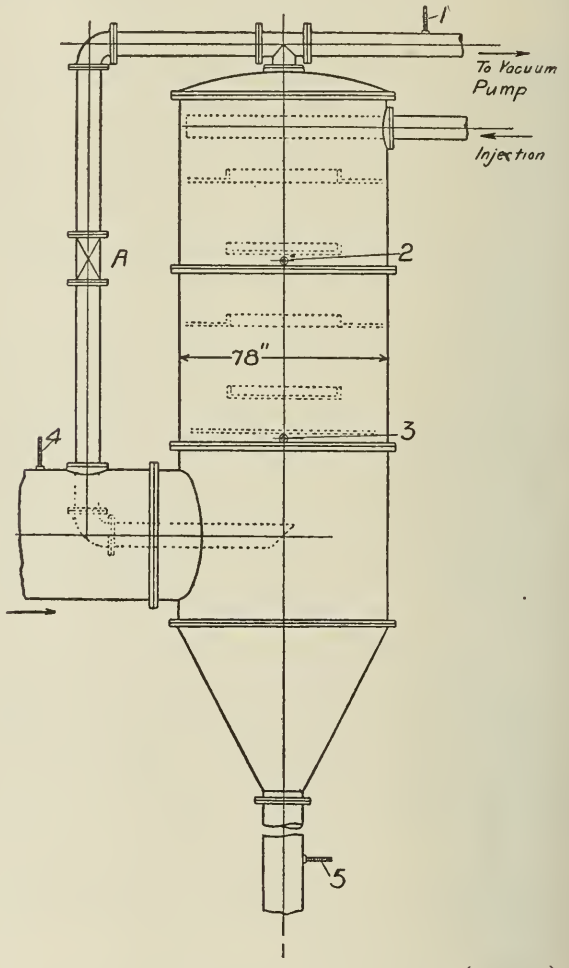


FIG. 1—COUNTER-CURRENT CONDENSER (TYPE I)

Fig. 1 illustrates a counter-current condenser upon which Professor Kerr made tests. Fig. 2 illustrates a parallel-current condenser which was also used in some of the tests. Referring to Fig. 2, it will be noted that the injection water enters the top, being controlled by a valve accessible to the operator. The water is sprayed and falls to one and then to another of two trays of semi-circular shape and finally to the bottom of the condenser and down the leg pipe. The trays are perforated with small holes, which cause a shower of water throughout the condenser. Vapors enter through the large pipe at the top and pass down-

ward. The air and other incondensable gases are swept toward the bottom, from there they are removed by the vacuum pump through the pipe shown, a conical thimble being placed so as to prevent water from entering the air pipe. The edges of the trays are serrated in sawtooth form to aid in dividing the overflow water into as finely divided a condition as possible, to facilitate an intimate mixture of water and vapor.

In the counter-current condenser of Fig. 1 the injection water pipe extends across the top and is perforated with small holes, thus spraying the water which falls from one to another of four circular trays with perforations and serrated edges. The vapors enter through the large pipe at the bottom and pass to the top, the air and other incondensable gases being drawn off by the vacuum pump through the connection shown. The

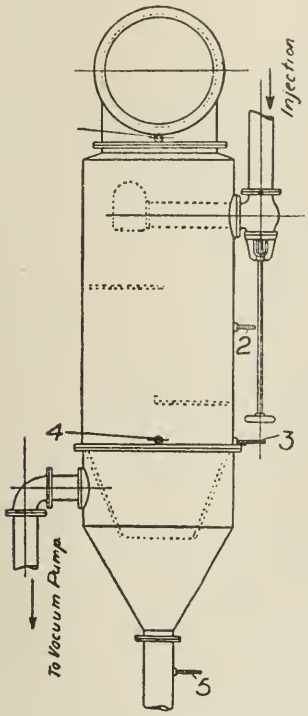


FIG. 2—PARALLEL-CURRENT CONDENSER (TYPE II)

valve A and its connecting pipe was put in for experimental purposes and was not a part of the original installation.

In the parallel-current condenser, Fig. 2, it will be noted that the air is drawn off near the bottom of the condenser, where the temperature is practically that of the leg pipe—that is, of the cooling water as it leaves. In Fig. 1, however, the air is drawn off from the top of the condenser just after having passed through the spray of cool injection water, and its temperature should be practically that of the entering injection. This is an advantage in that the vacuum pump will have a smaller volume of air to handle on account of its lower temperature. In other words, counter-current condensers should require a smaller vacuum pump displacement for a given amount of air handled than a parallel-current condenser on account of the reduced temperature. This difference in volume may amount to 10 per cent or more. An important consideration in condensers is that of the separation of vapors from incondensable gases so that the latter only will have to be handled by the vacuum pump. In this also the counter-current condenser seems to have the advantage.

Referring again to Fig. 1, it is evident that as the mixture of air and vapor move upward through the spray of cooling water, more and more of the vapor will be condensed, so that by the time the top is reached only air will be left, the injection with lowest temperature making it least possible for vapors to reach the air pump. On the other hand, with the parallel-current condenser, Fig. 2, the temperature of the water near the air discharge being relatively high, there is greater possibility of a mixture of vapor and air being drawn off by the air pump.

In any condenser the lowest pressure is at the coolest point, which is at the top in both the counter-current and the parallel-current types. In the counter-current condenser the air pipe is, therefore, at the point of least pressure, and the air should naturally move in that direction. In the parallel-current condenser, however, the air is taken off at the point of highest temperature, and, therefore, the highest pressure, a condition which does not facilitate separation of air from vapor. On account of the great specific volume of vapors under vacuum it is evidently of great importance to avoid handling vapors with the air pump.

In securing a good separation of vapors from air the size of the condenser plays an important part—in other words, the diameter of the condenser must be large in order to prevent excessive vapor velocities in it. If the velocity of the vapors is too high, there will not be sufficient time for complete admixture of water spray and vapors, and this will result in incomplete condensing

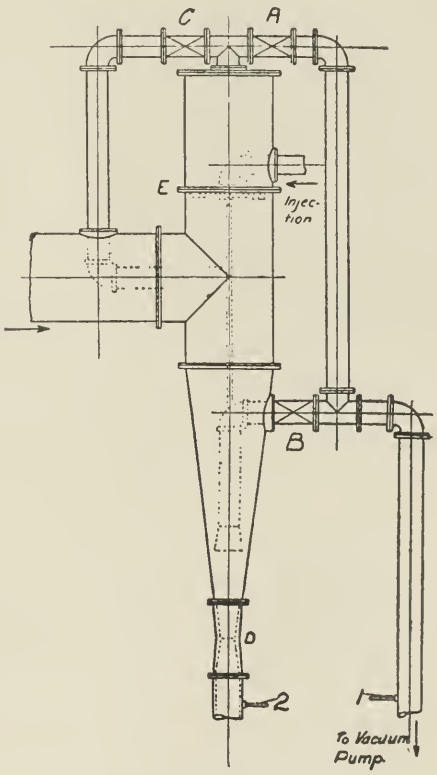


FIG. 3—CONDENSER (TYPE III)

of the vapors; in fact, the size has much to do with the results obtained from either parallel-current or counter-current condensers.

MIXING DEVICES

Attention has already been called to the use of trays having perforated bottoms and serrated edges, these trays being placed one above the other. In some cases only one tray is used, this being placed near the top, giving an uninterrupted shower from top to bottom. The latter would naturally give less time for contact of water and vapor, though it has the advantage of a

smoother flow of vapor through the condenser and a smaller velocity of the vapors. The trays naturally reduce the area of passage.

SUGAR HOUSE CONDENSERS WITHOUT VACUUM PUMPS

Fig. 3 illustrates a type of condenser in which the vacuum pump is often dispensed with. This condenser, as will be seen, is of the parallel-current type without trays, the original installation being that part below the flange *E*. The portion above *E*, including the valves *C* and *A* and their connecting pipes, were installed for experimental purposes. The vacuum pump connection belongs to the original installation, this being required for starting. Under normal operating conditions, however, the vacuum pump may be dispensed with, the air entering the condenser being entrained by the water passing through the restricted throat *D*. Even though the vacuum pump is used, its work is at least reduced by the aspirator *D*.

Tests of Condensers

With these different types of condensers Professor Kerr carried out a number of systematic tests. The condensers tested were of full size and used in the regular operation of evaporators or vacuum pans in sugar plants.

The object of the tests was to obtain especially first-hand information on the relative merits of the counter-current and parallel-current condenser types. In view of the fact that the advantages claimed for counter-current condensers are based on differences in temperature and pressure relation in the two types, the conditions of temperature and pressure were determined at different locations in the different types. Since the weight of cooling water required to condense a pound of vapor is an important consideration, attention was also given to this.

Tables III, IV, V give temperature observations from condenser types A, B, C respectively (Figs. 1, 2, 3). In each case thermometers were placed at points 1, 2, 3, etc., the observed temperatures being numbered to correspond in the tables. In all tests the temperature of the injection was constant and about 80 deg. Fahr.

Table III—Observations on Condenser Type I (Fig. 1)

Time	Temperature at 1	2	3	4	5	Vacuum, In. Mercury	Temp. Due to Vacuum, Kestner	Temp. Dif.	Conditions
1:45	122	83	132	134	113	25 5	130 0	17 0	Valve A open.
2:00	124	83	132	134	112	25.5	130 0	18	Valve A open.
2:20	125	83	134	136	114	24.5	137.8	23.8	Valve A open.
2:40	24	82	139	140	113	24.5	137 8	24.8	Valve A open.
3:00	106	83	132	134	112	25 25	132 0	20.0	Valve A closed.
3:20	99	83	140	142	115	24 0	140.8	25.8	Valve A closed.
3:40	96	81	134	137	113	24 5	137.8	24.8	Valve A closed
4:00	95	81	132	131	114	25.25	132.0	18.0	Valve A closed.
4:20	89	82	134	135	114	25 0	133 8	19.8	Valve A closed.
4:40	86	82	136	136	125	24 7	136 0	11.0	Valve A closed.
4:55	86	83	137	137	131	24 5	137.8	6.8	Valve A closed.
5:15	86	81 5	140	142	118	23 9	141 0	23 0	Valve A open 3 turns.

The observations given in Table III were made on a counter-current condenser. The arrangement of trays was somewhat different from that of the original installation, a plate just above thermometer No. 3 having been substituted for an annular tray like the top tray. The plate is of brass with perforations and its diameter only 6 in. less than the inside diameter of the condenser shell.

This substitution was made with the hope of improving the condenser. After the change, however, it was noticed that the condenser did not work smoothly, there being considerable vibration and noise attended with rapid fluctuation of the vacuum as shown by the mercury column vacuum gage. The conditions given in Table III were found with the condenser thus changed.

It will be noted that the temperature at 2 was only slightly greater than the initial temperature of injection. The thermometer must have been directly under a shower of water which, being out of the vapor path, had not been heated to any extent.

The readings from thermometer No. 1 in the suction pipe of the vacuum pump show interesting information. The first four readings were taken with the valve A open, establishing a direct connection between the hot vapor space at the bottom and the vacuum pump. With

Table IV—Observation on Condenser Type II (Fig. 2)

Time	Temperature at 1	2	3	4	5	Vacuum in Pan, In. Mercury	Temp. Due to Vacuum	Temp. Difference
10:40	130	129	...	114	109.4	25.5	130	20.6
10:50	130	125	...	114	98.6	24 5	137.8	39.2
						24 5		
11:00	130	130	108		104	25.3	132.0	28.0
11:10	126	126	108	111	105.8	26.1	134.5	28.7
11:20	135	124	105	106	107.2	26.4	121.0	13.8
11:30	137	129	107.3	110	105.8	26.2	124.5	18.7
11:40	137	128	107	108	104	26.2	124.5	20.5
11:50	136	128	107	108	105	26.2	124.5	19.5
12:00	137	123	107	106	100.8	26.4	121	20.2
12:10	136	124	108	107	104	26.3	122 5	18.5
12:20	136	127	110	108	106.4	25.8	127.0	20.6
12:30	132	131	116	112	107.6	25.4	131.0	23.4
12:40	124	124	107	104	103.4	26.1	129.0	25.6

Table V—Observations on Condenser Type III (Fig. 3)

Temperature at 1	Temperature at 2	Vacuum in Mercury	Temperature Due to Vacuum	Temperature Difference	Injection per Lb. Vapor, Lbs.	Conditions
126	122	24 6	137	15	25.1	Valve A closed. Valve B wide open.
124	117	24.6	137	20	28 7	Valves same. Injection increased.
115	107	24 7	136	29	40.1	Valves same. Injection increased.
121	117	24.6	137	20	28.7	A open 3 turns. Injection as at first.
118	114	24 7	136	22	31 4	A open 4 turns. Injection same.
118	114	24.5	137.5	23.5	31.4	A open 5 turns. Injection same.
118	115	24.5	137.5	22.5	30.5	Injection same. A wide open. B wide open.
119	116	24.8	135	19	29.2	Injection same. A same. B closed 3 turns.
118	114	24.7	136	22	31.4	Injection same. A same. B closed
121	115	25.0	134	19	30.4	Injection same. A same. B closed 9 turns.
114	111	24.4	138	27	24.7	Injection same. A open. B closed.

this condition the temperatures in the vapor pipe were some 8 to 12 deg. lower than the temperature corresponding to the vacuum. These relatively high temperatures indicate that the vacuum pump was drawing over a large amount of vapors. It will be noted also that those temperatures were considerably higher than the leg pipe temperature taken at the same time.

The last eight readings were taken with the valve closed and the temperatures observed may be assumed to show the conditions that may be expected with the normal operation of counter-current condensers. Here it will be noted that the temperatures at thermometer No. 1 ranged from 86 to 99, though the former probably comes nearest normal, the higher temperatures having been obtained immediately after closing valve A. These temperatures are some 40 to 50 deg. lower than the temperatures corresponding to the vacuum and very slightly above the temperature of injection, indicating air with very little vapor mixed with it.

Thermometers 3 and 4 show temperatures practically the same as that corresponding to the vacuum, the former being slightly lower than the latter, which is to be expected.

The average reading at 4 is slightly higher than that corresponding to the vacuum. This may be due to an error in the barometer reading, which was assumed to

be 30 in. This, however, will not affect the general value of the observations given in the table.

The temperature difference given in the last column of figures is the excess of the temperature corresponding to the vacuum over the leg pipe temperature. It varies from a maximum of 25.8 to a minimum of 6.8 deg., the latter figure having been obtained by a considerable reduction in the amount of injection water used. As stated above, most of the observations were obtained with an amount of injection water considerably in excess of that required by the condenser for the vacuum maintained.

These observations were taken while the condenser was handling the vapors from a quadruple effect, which was handling juice at the rate of about 400,000 gal. per 24 hr. The valve *A* and its connecting pipe was installed to ascertain if such a connection would do away with the vibration and noise caused by the substitution of the brass plate at the bottom, which has been mentioned. In subsequent tests of this condenser it was found that it could be operated with much less injection water than was used when these observations were made without reducing the vacuum. Further observations relative to this will be given later.

The observations given in Table IV were made on condenser Type II, Fig. 2, which is of the parallel-current type. This condenser serves a 12-ft. coil vacuum pan. At the time the observations were made a mixed strike with corresponding low purity was being boiled. Here we have greatly varying temperatures showing a considerable irregularity of conditions in different portions of the condenser. It will be noted that thermometers 3 and 4 show average temperatures only slightly greater than in the leg pipe shown by thermometer 5. Both thermometers 3 and 4 were doubtless affected by a flow of water over them, though the latter was in a current of vapor.

The relations of the temperatures found at 1 to the temperatures corresponding to the vacuum are somewhat irregular. This is probably due to rapid fluctuations of the vacuum causing a change in the one to be shown before the change has affected the other. The temperature in the suction pipe of the vacuum pump was not observed, though it was probably somewhere between the temperatures at 4 and 5—that is, in the neighborhood of 108 deg., a temperature much higher than that obtained with the counter-current condenser as shown by thermometer 1 in the latter part of table III. This high temperature indicates the presence of much vapor along with the gases. The excess of the temperature due to the vacuum over the leg pipe temperature varies from 13.8 deg. to 39.2 deg., the average being 22.8 deg. During most of the time the injection water valve was about as close as it was possible to have it without decreasing the vacuum.

Table V gives the results of observations on condenser Type III, Fig. 3. By means of the valves A and B and connection pipes it was possible to operate this condenser either counter-current or parallel-current—that is, with B closed and A open it operated counter-current and with B open and A closed it worked parallel-current. In the tests recorded in Table V the condenser was operated both ways, also while gradually changing from one condition to the other. The condenser was connected to the vacuum pump in all cases, though as heretofore explained the aspirator D did service in removing a portion of the incondensable gases.

In these observations only two temperature readings were obtained, namely, in the leg pipe and in the air pipe to the vacuum pump. The first three readings were taken while operating parallel-current, the injection being varied. It will be noted that the temperature in the leg pipe varied from 15 to 29 deg. above the temperature corresponding to the vacuum. The temperature in the air pipe for these three readings varied in the opposite direction with an average of about 120 deg., indicating a considerable quantity of vapors mixed with the air. The last three or four readings were taken with the condenser operating practically counter-current. In general there seems to be little difference in the results as regards temperatures when worked counter-current or parallel-current.

Pressure Relations

In comparing parallel-current and counter-current condensers it was stated that as a parallel-current condenser is hotter at the bottom than at the top, theoretically the pressure should be lower at the top—in other words, the pressure would vary at different points in condensers of either type. In order to ascertain if this difference of pressures actually existed, pressure observations were made in several different condensers.

In one counter-current condenser 5 ft. in diameter, serving a quadruple effect which delivered about 230 lb. of vapor to the condenser per minute, it was found that the pressure at the top was exactly the same as at the bottom. The comparison of pressures was made by means of a mercury manometer, one side of which was connected to the lower end of the condenser, and the other side to the top of the condenser, holes having been tapped into the bottom and top for the connection.

Another counter-current condenser 4 ft. in diameter serving a double effect and condensing about 180 lb. of vapor per minute gave a reading of 23.95 in. vacuum at the top and 22.5 in. at the bottom; that is, the vacuum at the top was 1.45 in. greater than at the bottom. This condenser had only one spray plate at the top, the water below it having an uninterrupted fall to the bottom.

A parallel-current condenser, with trays arranged practically as in Fig. 2 and handling vapors at the rate of about 110 lb. per minute, shows the same vacuum at the bottom as at the top, the vacuum being 22.46 in.

A parallel-current condenser, with three trays 2 ft. apart arranged as in Fig. 2, serving an 8-ft. vacuum pan, showed ¾ in. greater vacuum at the bottom at one time with three coils on and 1¼ in. greater vacuum at the bottom later with five coils on. The diameter of the condenser was 42 in. and it was condensing vapors at the rate of about 170 lb. per minute with a vacuum of 26 in.

At first sight it would appear that the results of these observations were quite contradictory. On investigation, however, it will be seen that the two condensers which have different vacuums at the top and bottom were relatively small and were handling larger volumes of vapor than in the case of the other two. It will be noted, also, that the higher vacuum in the parallel-current condenser was at the bottom, whereas in the counter-current condenser the higher vacuum was at the top. This seems reasonable as regards the counter-current condenser, though why there should be a higher pressure at the bottom of a parallel-current condenser is not so apparent, unless it be due to the pull of the vacuum pump.

Attention has already been called to the substitution of a plate instead of the original bottom tray in Fig. 1. It has been stated, also, that after this change there was considerable noise and vibration. After full consideration, it was thought that this might be due to a surging of vapors back and forth above and below this plate. On one occasion it was noted that there were twelve fluctuations at the vacuum gage of 1 in. every five minutes, the upward movement being much quicker

than the downward movement, the noise and vibration occurring at the beginning of the upward movement of the vacuum gage. The vacuum gage, which was of the mercury-column type, was connected to the space below the plate.

In order to get some data regarding this a mercury manometer was rigged up and one side connected to the space above the plate and the other side to the space below the plate. Upon operating the condenser again it was found that the mercury would vary, being first higher in one leg of the manometer and then suddenly reversing, showing that there was actual reversal of pressures in the condenser above and below the plate. This would naturally react upon the last body of the evaporator itself and cause unsteady action thereof.

It may be well to state here that the noise and vibrations spoken of usually occurred when the supply of injection water was reduced to a point where the leg pipe temperature was very near that of the temperature due to the vacuum. After the fact of these pressures reversals was established the plate was gradually reduced in diameter from time to time until a space of 9 in. was left between the plate and the shell, at which point the vibration ceased and the condenser worked smoothly.

All of the pressure observations seem to be of value mainly in pointing out the desirability of liberal size and careful designing of trays, both as to size and location, in order to secure steady action and the prevention of pockets.

Quantity of Injection Water

The unit assumed for measuring injection water is, "pounds of injection water per pound of vapor condensed." The point has already been brought out that for a given absolute pressure in the condenser the amount of cooling water depends mainly upon the amount of air or other incondensable gases mixed with the gases in the condenser. The presence of air results in a higher leg-pipe temperature than there would be if no air were present. Theoretically, the greater the amount of cooling water the greater the vacuum due to the cooling effect. Actually, however, there is a limit to this because the water brings in air with it which offsets the reduction in pressure due to cooling. This is especially so in condensers with a poor separation of air from vapor. The weight of cooling water per pound of vapor has to be calculated from temperature and vacuum data, as it is not practicable to actually weigh the water; however, the calculated values are quite accurate.

Tables III and IV give data bearing upon the weight of cooling water per pound of vapor, though indirectly. Other conditions being the same, the weight of cooling water per pound of vapor is almost proportional to the difference between the temperature corresponding to the vacuum and the leg-pipe temperature. It will be noted that in Table III this value varies from a minimum of 6.8 deg. to a maximum of 25.8 deg—that is, the maximum is nearly four times the minimum. It will be noted, also, that the vacuum was less with a large temperature difference than with a small temperature difference. These observations were made on a counter-current condenser handling in the neighborhood of 550 lb. of vapor per minute. The minimum difference shows something of what can be done with careful manipulation of the injection water.

Table IV, giving the observations on a parallel-current condenser serving a vacuum pan, shows a minimum difference of 13.8 deg. and a maximum of 39.2 deg. The temperature difference in all cases is much higher than is considered good in practice. A minimum difference of 13.8 deg. is probably about the best that could be done with this condenser. It will be noted, also, that this was obtained with the highest vacuum observed in the series.

Table V gives values of injection per pound of vapor varying from 24.7 to 31.4 lb. The temperature difference is in all cases very high.

Table VI—Observations on Condenser Type IV

Vacuum	Temp. Due to Vacuum	Temp. Leg Pipe	Temp. Difference	Injection Water per Lb. of Vapor, Lbs.	Conditions
24.5	137.5	120	17.5	26.5	
24.5	137.5	120	17.5	26.5	Injection valve open an additional turn
24.6	137	119	18.0	27.2	Same.
24.65	136.5	116.5	20.0	29.2	Same.
24.5	137.5	120	17.5	26.5	As at first.
24.25	139	124	15.0	23.8	Injection valve closed one turn.
23.8	142	127	15.0	22.3	Injection valve closed two turns.

Note.—In no case could the injection valve be altered without affecting the vacuum. Type IV condenser is the same as that part of Type III condenser below flange E.

Table VII—Observations on Condenser Type V

Vacuum	Temp. Due to Vacuum	Temp. Leg Pipe	Temp. Difference	Injection Water per Lb. of Vapor, Lbs.	Conditions
25.0	134	118	16.0	28.2	
24.9	134	120	14.0	26.4	Injection valve closed one turn.
24.8	135	123	12.0	24.4	Injection valve closed 2 turns.
24.65	136.5	126	10.5	22.8	Injection valve closed 2½ turns.
24.5	137.5	130	7.5	20.8	Injection valve closed 3 turns.

Note.—In no case could the injection valve be altered without affecting the vacuum. Type V condenser is the same as that part of Type III condenser below flange E.

Table VIII—Observations on Condenser Type I

Vacuum	Temp. Due to Vacuum	Temp. Leg Pipe	Temp. Difference	Injection Water per Lb. of Vapor, Lbs.	Remarks
25.5	130	130	0	20.8	
26.5	121	120	1	26.2	
25.75	128	125	3	23.2	
26.25	123	120	3	26.5	
25.5	130	130	0	20.8	
24.8	135	130.3	5.2	19.9	Average during evaporation test. See test 3, Table 14.
24.8	135	112.9	22.6	35.0	Average during evaporation test. See test 1, Table 14.
25.1	133	114.2	19.3	32.6	Average during evaporation test. See test 2, Table 14.

Note.—During the time the first five observations were made the injection valve was not changed, the five observations being made within a space of about two minutes.

Tables VI, VII and VIII give data which may be used for comparing the amount of cooling water required with the two types of condensers shown in Figs. 1 and 3.

It will be noted that in Table VI the amount of injection water used was varied, though the amount of vacuum in the first five readings remained practically the same. In the last two observations, however, with reduced injection the vacuum decreased, the temperature difference remaining at 15 deg. In other words, we may be assured that with this condition the minimum possible temperature difference was obtained.

The observations shown in Table VII give temperature differences ranging from 16 down to 7.5, with greatly decreasing vacuum. Here, also, the equilibrium point was obtained, the average temperature difference being something like 12. Condenser Type V is exactly like condenser III, Fig. 3.

The first five observations of Table VIII were obtained in an attempt to ascertain the lowest possible injection water requirement for condenser A, which is of the counter-current type. It will be noted that the

average temperature difference for these five observations was a little less than 15.

With the minimum temperature difference of 7.5 for condenser Type V the weight of cooling water for a vacuum of 26 in. and the injection temperature of 80 deg. would be 27.07 lb. With a temperature difference of 14, the weight of cooling water for the same standard conditions would be 23.24 lb. In other words, the counter-current condenser would seem to be capable of operating with some 17 per cent less cooling water than is required for condenser Type V.

The last three horizontal lines of Table VIII give the averages obtained during evaporator tests using condenser Type I. It will be noted that the weight of cooling water per pound of vapor varies from 19.9 to 35.0 lb. with the same vacuum, the difference being doubtless due to carelessness in handling the injection valve.

Table IX gives condenser data obtained by Professor Kerr while making various evaporator and vacuum pan tests. This table gives data of considerable interest, though it is not very definite as regards a comparison of counter-current and parallel-current condensers.

TABLE IX

1	2	3	4	5	6	7	8	9	10	11	12	13	
Service	No. of Test	Vapor Condensed per Minute, Lbs.	Type of Condenser	Diam. Condenser, Inches	Vacuum	Temp. due to Vacuum	Temp. Leg Pipe	Temp. Difference	Temp. Injection	Injection per Lb. Vapor, Lbs.	Injection per Lb. Vapor, Corrected, 26" and 80°	Vapor Velocity (Gross) in Condenser, F. P. S.	Remarks
Quad	1	534	Counter current	78	24.8	135.0	112.9	22.6	80.4	31.94	45.58	37.3	
Quad	2	588	Counter current	78	25.1	133	114.2	19.3	80.4	30.67	40.93	43.1	
Quad	3	610	Counter current	78	24.8	135	130.3	5.2	81.0	20.7	26.26	42.5	
Quad	4	410	Parallel current (Spec.)	36	24.1	140.5	114.5	26.0	81.0	31.00	55.34	118.5	
Quad	5	452	Parallel current (Spec.)	36	23.5	144.0	115.4	28.6	80.4	29.7	64.0	118.2	
Quad	6	327	Parallel current (Spec.)	36	25.4	130.5	112.3	18.2	80.0	32.1	39.25	.....	
Quad	7	185	Counter current (central)	.....	26.9	118.0	116.3	17.0	66 2	20.62	17.7	.....	
Quad	8	292	Counter current (central)	.....	26.2	124.0	111.2	13.8	66.2	23.0	33.66	.....	
Quad	9	173	Counter current (central)	.....	26.0	125.5	122.1	3.4	66.6	18.46	25.1	.....	
Quad	10	230	Counter current	60	26.3	122.5	114.5	7.9	92.8	47.28	28.22	36.7	
Double	15	182	Counter current	48	22.06	152.4	146.6	5.8	64.6	12.33	26.67	22 .0	
Double	16	180	Parallel current	.....	24.77	135.6	118.0	17.6	72.4	22.66	38.38	.....	
Vacuum pans	1	217	Parallel current	54	24.06	140.4	109.4	31	81.0	36.75	74.77	27.9	Straight strike.
Vacuum pans	2	153	Parallel current	54	25.0	133.8	104.6	29.2	81.0	44.31	66.4	23.7	Mixed strike.
Vacuum pans	3	69	Parallel current	54	25.8	127.2	94.7	32.5	81.0	76.84	83.52	12.9	Crystallizer strike.
Vacuum pans	5	112	Parallel current	.....	25.58	129.9	119.1	10.8	86.5	31.57	30.66	.....	
Vacuum pans	.....	245	Counter current (central)	.....	23.6	143.3	125.5	17 8	70.0	18.5	38 66	.....	
Vacuum pans	.....	265	Counter current (central)	.....	22.92	147.3	124 3	23 0	70.0	19.0	47.83	.....	

The actual injection per pound of vapor is given in column 11. These values, however, were obtained with varying vacuums and varying temperatures of injection water, for which reason they are not directly comparable. For this reason the weight of injection water per pound of vapor has been corrected to a standard vacuum of 26 in. and an injection temperature of 80 deg. These corrected values are given in column 12.

The values in column 13—namely, vapor velocities in condenser—are based on the assumption that a condenser is a cylinder without trays, and equal to the cubic feet of vapors per second divided by the cross-sectional area of the condenser shell. The results, though, are somewhat erratic, and this is quite natural in view of the careless operation of many of them.

A general inspection of column 12, however, shows considerable advantage for the counter-current type of condenser. The average of ten tests made on the counter-current condenser shows 33.06 lb. of injection per pound of vapor condensed. An average of eight tests made on parallel-current condenser shows 56.3 lb. of injection per pound of vapor condensed. Condensers Type I and Type V were in the same factory and observations were made throughout several weeks in order to get a comparison of the actual weight of the cooling water required per pound of vapor in the regular operation of the factory. The average temperature difference for condenser Type I was 16.5 deg. and for condenser Type V 25.5 deg. With standard conditions—that is, with 26-in. vacuum and 80-deg. injection water—these temperature differences would correspond to 35.8 lb. of injection per pound of vapor in the case of condenser I and 52.3 lb. for condenser V; in other words, condenser V required 43 per cent more injection water than condenser I. This shows a greater difference than was shown in the observation referred to above.

Anaconda Notes.—From the June issue of *The Anode*, the safety bulletin published by the Anaconda Copper Mining Co., we note that No. 1 section of the concentrator, which was recently remodeled to provide for the installation of the oil flotation process, is successfully treating ore at the rate of 2000 tons per day and is making a tailing that assays well within the limits expected. No. 2 section is now being changed to provide for the use of the same process and rapid progress is being made with the work. It is expected that the entire task of tearing out the old machinery and constructing the new 2000-ton section, ready for operation, will be accomplished by August. All four furnaces in the East Reverberatory Building are now operating on pulverized coal. Three of them are 143 ft. in length and the fourth, which was the first furnace to be equipped for coal dust firing, is 124 ft. long. These four are running nicely and are smelting a greater amount of material than the eight grate-fired furnaces formerly did. All furnaces in the West Building are now being rebuilt and will be ready for operation when the No. 2 Roaster Plant is completed. In the Coal Pulverizer Plant the Pulverizer Building is now completed and work is progressing on the installation of the balance of the crushing, storage and drying equipment.

The Morse Bros. Machinery and Supply Company, of Denver, Col., has purchased the entire power plant recently erected at Wilkenburg, Ariz. This plant was built to furnish power for the Octave Mining Company, fourteen miles distant, the power being generated at the railroad and transmitted to the mine. The plant consisted of 200 and 550-kw. Westinghouse alternators driven by Corliss engines. The steam plant consists of B. and W. Boilers, fired with oil. The transmission line was operated at 22,000 volts and is fourteen miles long. All of this material will be dismantled and sold, or removed to Denver. The smaller unit was in use three weeks and the larger one was never used.

The Electric Furnace for Reheating, Heat Treating and Annealing*

BY T. F. BAILY

More than a quarter of a century ago the first commercial electric furnace was put into operation for the melting of steel. This furnace, of less than 100 kw. capacity, showed on its preliminary operation a current consumption of 7000 kw.-hr. per ton of metal melted. Had this furnace been operated in America at the then commonly prevailing rate for electricity, at, say, 10 cents per kilowatt-hour, there would have been little hope that such a process requiring a heating medium of such great cost would ever become commercial. In the twenty-five years that have passed since this early and crude development of electric melting and refining furnaces, there have been put into service more than 100 of these furnaces, ranging in commercial capacity from 1 to 20 tons, and in electrical capacity from 100 to 3000 kw. Central stations that twenty-five years ago considered 10 cents per kilowatt-hour a low rate are now, with modern equipments of power generation, furnishing electric furnaces with current for less than ¾ cent. Electric furnace loads running into thousands of kilowatts, where now there are but hundreds, operating continuously and with power factors closely approaching unity, will undoubtedly cause central stations advantageously located to look with favor upon rates of ½ cent a kilowatt for such loads. As the dominating factor in electric furnace operation costs must always be the cost per kilowatt-hour, the gradual reduction in the cost of electric current will greatly add to the growth of electric furnace loads for re-heating, heat-treating and annealing.

Early Methods of Re-Heating by Electricity

One of the earliest attempts at electric heating was by direct resistance, wherein the materials to be heated were clamped between two massive terminals of an electric circuit, or, as in the water pail forge for small material, where one end of the bar was connected to a suitable terminal while the free end of the bar was plunged into a bath of water and other suitable liquid conducting material which was in turn connected to the other terminal of the electric circuit.

Both of these methods have two distinct disadvantages which prevented them ever becoming commercially feasible. The first and most serious is the matter of obtaining a suitable contact between the material to be heated and the electric terminal. The other inherent disadvantage is that at the point where the electric connection is made that part of the material to be heated must of necessity be of a different temperature than the rest of the bar.

From an operating standpoint, this method of heating is very inconvenient, as electrical connection must be made for each piece to be heated, and on account of the enormous current involved these contacts must be carefully made or there will be serious burning of the metal at this point, which would not only destroy the electrical terminal itself, but also burn the bar.

In any event, this method of heating could not be adapted to any but material of uniform cross-section, and in all probability there would be a much higher temperature in the interior of the bar than on the surface, due to the peculiar heating effect of an electric current flowing in a conductor.

Re-Heating Furnaces with Granular Resistors

The type of furnace that seems best adapted for reheating operations is the resistance type, in which the material to be heated is entirely separate from, and independent of, the resistance elements in which the heat is generated by the electric current. This arrangement makes for the maximum simplicity and convenience in operation. A general description of this type of furnace is as follows:

Through the side walls of a furnace shell made of suitable refractories are inserted two carbon or graphite electrodes. The inner ends of these electrodes extend into a trough of highly refractory material. This trough is filled with the resistance material itself, usually some form of broken carbon, and makes contact at each end with the electrodes. The outside ends of the electrodes are connected by means of suitable copper terminals and cables to the regulating transformer and switch, by means of which the voltage impressed across the furnace is regulated, the voltage thrown on the furnace having a definite relation to the current flow and heat input. The material to be heated is placed conveniently adjacent, at the side or above or underneath the resistance material and its containers, as the case may be.

In some heating operations the actual cost of heating per ton is less with electric furnaces than with combustion furnaces, while in some heat-treating and annealing operations the precision with which the operations are carried on must be the justification for the higher cost of heating in the electric furnace. In a general way it may be stated that the higher the temperature at which the heating operation is conducted the higher the relative economy in the use of electric furnaces. At the lower temperature there is less difference in the thermal efficiency of electric and combustion furnaces, but here the electric furnace shows great superiority in the way of temperature control.

The principal advantages of electric furnaces over combustion furnaces for re-heating are more accurate temperature control, non-oxidizing atmosphere, saving in space, elimination of blast or stack, evenness of temperature throughout the heating space, simplicity of control, small amount of heat lost to the surrounding atmosphere, and cleanliness of surroundings.

Electric furnaces of the character described may be controlled with great precision, for the reason that a given input of electric current liberates a given quantity of heat units within the furnace, the transfer of electric current to heat being at 100 per cent efficiency. The walls and doors of the furnaces are the only means for the escape of heat from the furnace in other than useful work, and this loss remains constant for any given temperature and operating conditions. For a given tonnage of metal to be heated to a certain temperature in a given time, it is only necessary to know the heat absorbed by the metal in coming to the temperature and the heat lost by conduction and radiation from the furnace. The voltage across the furnace terminals is then adjusted so that the kilowatts per hour required to deliver the necessary heat are just sufficient to deliver this heat.

In contrast with this simple method of delivering heat into the furnace, the combustion furnace requires that a given quantity of air be mixed with the fuel, and this process of converting chemical energy into heat is not usually conducted at an efficiency closely approaching 100 per cent, as in the conversion of electricity into heat. Besides this, the stack or discharge flues to the combustion furnace are an ever present means of carrying out what should have been useful heat under ideal operating conditions. Any variation in the supply of air or the supply of fuel in a combustion furnace quickly

*A paper presented before the Engineers' Society of Western Pennsylvania. In connection with this paper former papers by Mr. Baily may be compared in our Vol. 9, page 262 (May, 1911), and Vol. 10, page 291 (May, 1912), where illustrations of this furnace type may be found. An illustrated description of a Baily annealing furnace for brass and German silverware was given in our Vol. 12, page 483 (July, 1914).—Editor.

affects the temperature, and both of these do continually vary, both in volume and pressure.

In order to obtain good commercial efficiency in a combustion furnace, an excess of air over the theoretical amount is required. This excess of air creates an oxidizing atmosphere in the furnace chamber which results in scaling the metal under treatment, resulting in a loss of from 1 to 5 per cent, depending upon the type of combustion furnace, the temperature, and the man operating the furnace. The smaller of these figures applies to annealing furnaces of large capacity, while the larger figure is not uncommon in oil or gas-fired heating furnaces for forging stock running at high temperatures. One of the factors contributing to the reliability of electric furnace operation is that electric current supply, whether from central station or from isolated plants, is much more dependable than either oil or gas, and under more ready control than even direct firing.

The space required for electric furnaces is considerably smaller than that required by combustion furnaces, due to the fact that no stack nor combustion chamber is required, and the electric cables carrying current to the furnace require much less space and are far safer than gas or oil lines, and much more readily located.

As the heat from the resistance units is thrown on the hearth almost entirely by radiation, the temperature of the furnace is more readily kept uniform over the entire area than in combustion furnaces where the heat is delivered to the hearth by the impinging heated gases or products of combustion. Another feature leading to evenness of temperature throughout the electric furnace is that the resistors of the electric furnace may be run at only a comparatively small temperature above that of the hearth of the furnace, while the combustion furnace, for instance in an annealing operation, requires that the incoming gases from the combustion chamber must of necessity be several hundred degrees higher than the desired ruling temperature of the furnace.

Mention has already been made of the precision with which electric current may be supplied to the furnace. It should be noted further, however, that the instruments for indicating and recording electricity are far more accurate than those available for indicating and recording the flow of fuels to combustion furnaces. Thus the heating costs of electric furnaces may be very readily obtained on any particular class of work, as the kilowatt-hours registered over a given run are readily ascertained.

In the summer months the heat given off by combustion furnaces, either by radiation through the walls of the furnace itself or from the waste products of combustion, if small furnaces are used, produces such extreme room temperature around the furnaces as to seriously affect the operator and markedly reduce the output of the furnaces. In contrast with this the loss of heat through the walls of an electric furnace is so small as to be almost negligible.

The actual theoretical heat required expressed in kilowatt-hours per ton of metal is given in Table I for heating to the temperature given.

The thermal efficiencies of electric furnaces vary greatly with the size and capacity in tons per hour. The wall loss on a forging furnace of 60-kw. capacity heating 250 lb. of steel per hour to 2200 deg. Fahr., will be approximately 30 kw., showing a thermal efficiency of 50 per cent. A furnace of 1 ton per hour capacity for 2200 deg. will show an efficiency of 75 per cent.

In annealing work a furnace of 100-kw. per hour capacity will heat 600 lb. of metal to 1650 deg. with an efficiency of 50 per cent, while a furnace of 600-kw. capacity heating 3 tons of steel per hour will show an efficiency as high as 90 per cent. All the above figures are typical for the usual classes of work handled in the capacity named.

First Commercial Furnace for Re-Heating

The first type of these granular resistor furnaces for re-heating was designed for heating small bars and billets such as are used for small forgings, and for temperatures up to 2300 deg. The general construction of these furnaces was as follows: The furnace proper was constructed of firebrick much after the method of prevailing oil-fired furnaces. Through the sides of the furnace were inserted large electrodes, the inner ends protruding into the furnace chamber. Foundry coke crushed to pea size was placed in the space between the electrodes and formed the resistor of the furnace. The opening to the furnace was in front, and the bars of metal to be heated were placed directly over the resistance body but not in contact with it. The necessary variable voltage supply to this furnace was regulated by the field rheostat of a small single-phase alternator. This furnace was run commercially for several weeks in place of the oil-fired furnace usually used for the hammer and on various sizes of material, as shown by the data given in Tables 2 to 5.

TABLE I

Material	Deg. Fahr.	Kw.-Hr. per Ton
Iron	2200	230
Iron	2000	215
Iron	1800	200
Iron	1650	170
Iron	1500	150
Iron	1250	115
Iron	900	75
Copper	1400	90
Brass	1300	85
Aluminum	950	140
Aluminum	750	110
Silver	1300	50
German silver	1300	75

TABLE II

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
9.50	150	270	6	1¼x132	10.15	10.25	10.45
10.55	160	260	3	1¼x 66	11.11	11.15	11.28
12.23	150	270	8	1¼x180	12.38	12.44	12.55
1.00	153	260	8	1¼x180	1.12	1.20	1 37

TABLE III

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
9.25	127	340	8	1¼x⅞x5 ft. 10	9 33	9 38	10 42
10 51	122	350	8	1¼x⅞x5 ft. 10	10 58	11 01	11 19
12.32	128	330	Metal un forged at noon		12 38	12 41	1 25
1.27	132	330	8	1¼x⅞x5 ft. 10	1.35	1.38	2 44

TABLE IV

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
1 20	230	180	5	1¼x24	1 40	1 51	2 07
2.08	230	180	7	1¼x24	2 30	2 31	3 08
3.17	208	200	7	1¼x24	3 30	3.36	3 52
3 55	204	200	7	1¼x24	4 01	4 07	4 29

TABLE V

Time of Charging	Volts	Amperes	Number Pieces	Size Stock in Inches	First Cut	Second Cut	All Out
3.55	240	140	8	⅞x27	4 00	4 02	4 25
4.26	172	150	8	⅞x 9	4 30	4.33	4 36
4.37	252	120	9	⅞x22	4 40	4 44	4 55
4.57	280	120	8	⅞x 9	5 01	5 04	5.07

Some of the difficulties encountered in this furnace besides its rather low thermal efficiency were burning off of the electrodes at the point where they emerged from the furnace; the burning out of the refractory materials supporting the resistance material itself; trouble with electrical connections between furnace cables and electrodes, and great variation in the electrical resistance of the resistance material itself.

The Electric Furnace for Re-Heating

In the six years that have elapsed since the construction of this early furnace, these difficulties have been well overcome. By the use of a steel shell for the outside wall of the furnace instead of brick, and with this space filled with suitable insulating material, the thermal efficiency of the small furnaces has been very materially increased, as is shown by the accompanying test sheet on a 30-kw. furnace. The burning off of the electrodes at the place where they leave the furnace walls has been entirely eliminated, one set of electrodes lasting for months at a time in continuous service.

Table VI—Test of a 30-K.W. Electric Furnace

Time of Charge	Watt-meter, Kw.-Hr.	Voltage	Temperature of Stock	Number Pieces ½"x⅝" x16"	Remarks
Start 5.15 p.m. 5.30	10,971 10,981	25	2200	15	Estimated initial temperature of furnace, 2400 deg. Fahr.
Start 5.40 5.55	10,981 10,990	25	2200	15	Voltage changed to 30 at 5.45. Voltage changed to 25 at 5.50.
Start 5.55 6.13	10,990 10,999		2200	15	
Start 6.13 6.30	10,999 11,009	25	2200	15	Voltage changed to 30 at 6.28.
Start 6.30 *6.50	11,009 11,019	30	2200	15	Voltage changed to 25 at 6.40. Voltage changed to 30 at 7.20.
Start 7.28 7.49	11,033 11,052	30	2200	15	Voltage changed to 25 at 7.41.
Start 7.54 8.12	11,055 11,068	25	2200	15	Voltage changed to 30 at 7.54. Voltage changed to 25 at 8.05.
Start 8.18 8.33	11,072 11,080	25	2200	15	Voltage not changed.
Start 8.38 8.56	11,082 11,093	25	2200	15	Voltage changed to 30 at 8.48.
Start 9.01 9.20	11,098 11,110	30	2200	15	Voltage changed to 25 at 9.03.
Start 9.27 9.43	11,112 11,120	25	2200	15	Voltage not changed.
Start 9.49 10.20	11,122 11,138	25	2200	15	Voltage changed to 30 at 10.00. Voltage changed to 25 at 10.11.

Duration of test, 5 hrs., 5 min.
No resistance material used. Current left on at 20 volts.
11,138−10,971=167 kw.-hr. power used.
½×⅝×16×0.2834=4.25 lb. weight per bar of steel.
15×12=180, total number of bars heated to 2200 deg. Fahr.
4.25×180=765, total number of lb. of steel heated to 2200 deg. Fahr.

$$167 \div \frac{765}{100} = 21.83 \text{ kw.-hr. per 100 lb. of metal heated.}$$

20×21.83=436.6 kw.-hr. per ton of metal heated.
Temperature difference, 2150 deg.
Specific heat of steel, 0.199 approx.
2150×0.199×765=327.305 B.t.u. required to heat metal.
167×3412=569.804 B.t.u. used in furnace.

$$\frac{327.305}{569.804} = 0.575 \text{ efficiency.}$$

*One piece removed that had obtained required temperature.

The troubles encountered in connecting the electric cables to the electrodes have been eliminated, so that no trouble is experienced now from this source. For furnace temperatures not exceeding 2500 deg. Fahr. this type of furnace will answer every reasonable requirement, and in operating cost will compare very favorably with oil furnaces, figuring electrical energy at 1 cent per kilowatt-hour and oil at 4 cents per gallon, so far as actual fuel cost alone is concerned, while there is an additional saving due to the non-oxidizing of the metal amounting to a saving of from 2 to 5 per cent of the metal heated. This type of furnace is suitable for tonnages up to 1 ton per hour capacity, and billets not exceeding 4 ft. in length.

Continuous Furnaces

For furnaces in capacities of 1 ton per hour and above, the continuous type of billet heating furnace offers some advantage in economy as well as in mechanical operation, as in the continuous type only the discharge end of the furnace reaches the full ruling temperature, the lower temperature of the feeding end reducing wall loss of the furnace very materially. The following calculation of a heat balance sheet may be taken as typical for this type of continuous billet heating furnace heating material to 2000 deg.:

Capacity, 10 tons per hour; temperature, 2000 deg.; wall loss in kilowatt-hour, 250; theoretical heat required per hour by metal in kilowatt, 2150; kilowatt-hours per ton of metal heated, 240; cost of heating per ton with current at ½ cent per kilowatt, $1.20.

This figure of cost per ton of metal heated becomes prohibitive unless account is taken of the metal loss due to the oxidizing influence of the flame in gas-fired billet heating furnaces. Even making allowances of 2 per cent on $20 steel, this type of furnace seems to have no prospect of competition for large tonnages unless the cost of electric current is under the rate named in the above tabulation. In heating higher grades of steel, especially steel of crucible quality, the saving in scale over any combustion furnace practice will far outweigh the higher cost of heating by the electric furnace.

Combination Gas and Electric Furnaces

In large tonnages of heavy billets a combustion furnace using producer gas firing to, say, 1500 deg. Fahr., or above, and heating from this temperature to the desired rolling temperature by electricity, offers advantages of low fuel cost per ton of metal heated, at the same time a minimum amount of oxidation of the metal, as the low ruling temperature of the gas end will permit a high thermal efficiency even with a non-oxidizing flame, while the final heating is done in the electric end of the unit which is readily maintained under a reducing atmosphere.

Such a furnace as this can be expected to show a thermal efficiency in the gas end of 50 per cent and in the electric end 75 per cent. With coal at $2 per ton and electricity at ½ cent per kilowatt, the total cost of heating should not exceed for coal alone 10 cents and electricity 32½ cents, making a total cost of 42½ cents per ton.

This cost compared with a direct-fired heating furnace having a coal consumption of 200 lb. per ton of metal heated, would show an excess cost for the combination gas and electric furnace of 22½ cents per ton. But with a saving of 2 per cent in metal worth $20 per ton, the combination gas and electric furnace would show an actual saving of 17½ cents per ton of metal heated, besides giving to the metal all the advantages of the precision in uniform temperature throughout the billets, as well as a uniform rolling temperature.

Soaking Pits

The type of electric furnace which seems, however, to be destined to have the largest commercial application in rolling mill operations is the soaking pit, and it is doubtful whether any gas-fired pits of large size can compete in cost of operation with electric pits where

current is supplied at the usual rates of electric current available for this service, provided the ingots are charged hot into the furnace. A heat balance sheet for an hour-hole soaking pit holding sixteen 3½-ton ingots and having passed through it 648 tons per twenty-four hours would be as follows, assuming a wall loss of 500 kw. per hour:

With ingots stripped hot, interiors molten, no heat required for the metal itself, the current consumption would then be 500 kw.-hr. per 27 tons of ingots, or less than 20 kw.-hr. per ton of ingots soaked. With ingots averaging 1650 deg., the current consumption for 27 tons per hour would amount to 1620 kw. per hour, or a current consumption of 60 kw.-hr. per ton absorbed by the metal. To this should be added 40 kw.-hr. per ton as wall loss. This higher figure for wall loss per ton of metal heated being due to the reduced capacity of the pit in tons per hour when handling the cold ingots on account of the longer time required for heating and soaking. Thus the current consumption for ingots charged at 1650 deg. would be 100 kw.-hr. per ton.

With cold ingots the heat absorbed by the metal will be 230 kw.-hr. per ton, and with a wall loss under this condition of 185 kw.-hr. per ton 315 kw.-hr. per ton would be the current required for cold ingots. But as cold ingots are a rather small percentage of the total ingots handled in a modern steel mill, these high figures are of no serious consequence in considering electric furnaces for soaking pit operations.

It is apparent from these calculations that electric soaking pits can compete with gas-fired pits, even where moderately hot stripping and charging is practised. Besides this, the electric pit, as in the heating furnaces mentioned before, has the advantage of a non-oxidizing atmosphere, which will mean a saving of from 1 to 2 per cent of the weight of ingots put through the pit. Another advantage worthy of note is that an electric pit will take only one-third the space of a gas-fired pit of the same capacity. A feature of even greater importance than almost any other is the elimination of surface defects in the ingots, due to scale or oxidation, a matter now receiving considerable attention by steel makers.

Electric Furnaces for Heat Treating and Annealing

The rapid growth of the practice of heat-treating and a realization of the precision with which this treatment must be carried on in order to secure uniform results, has opened a particularly desirable field for the electric furnace, especially as the electric furnace can be more accurately controlled and a greater uniformity of heat throughout the furnace maintained in commercial operation than with combustion furnaces. A comparatively slight variation in either blast pressure or fuel supply in a combustion furnace very quickly affects the ruling temperature, while in the electric furnace, owing to the comparatively great mass of heated refractory material of walls and roof acting as a heat storage or accumulator, the variation in temperature is reduced to a minimum. In practice the current may be off for periods of an hour at a time without affecting the temperature more than a few degrees.

This type of furnace may be described as follows: In the usual steel sheet is constructed an arched roof of firebrick, so arranged as to reflect the heat radiated from the resistor troughs onto the hearth located between the two resistor units running lengthwise of the furnace. The material to be heated is handled through the doors of the furnace located in the end walls. The hearth, if not subject to mechanical abrasion, is made of suitable firebrick. Where the abrasion is likely to be severe, cast-iron plates replace the firebrick.

A heat balance sheet of a furnace of this type of 100-kw. capacity and the hearth area 5 by 6 ft. and heating 600 lb. per hour to 1650 deg. Fahr., will show the following efficiencies:

Heat absorbed by the metal, 50 kw.
Heat lost through the walls, 35 kw.
Heat lost through the doors and door openings, due to the frequent charging and withdrawing, 15 kw.

Continuous Furnaces

For furnaces of more than ½ ton per hour capacity, and for higher thermal efficiencies, the continuous type of furnace is desirable. The material, if of uniform section, is pushed through the furnace by direct application of the pusher to the material to be heated. If the parts are small or liable to buckle if direct pressure is exerted on them, they are placed in pans or steel boxes, these containers being pushed through one at a time. If the material is in the form of rods that may be handled through the furnace lengthwise, as, for instance, copper and brass rods or tubes, this material may be placed on steel pans and drawn through the furnace by means of hook and chain, as is common in brass mill practice.

A typical furnace of the continuous type for annealing German silver or brass stampings in steel pans has a hearth 15 ft. long by 2 ft. wide, and a rated electrical capacity of 200 kw. A mechanical charger operated by a motor-driven winch with hand-operated clutch pushes the pans in through the charging door one after another, seven pans being in the furnace at one time. The pans passing through the furnace are supported by a hearth made of cast-iron grids each 2 ft. square. The pan when discharged is dumped automatically into a water-sealed discharge hood. The metal under treatment falls into a tank of either clear water or pickling solution, depending upon the cleanliness of the material before it is charged. The pan is caught by two rails and held suspended above the trough. It may be taken out from under the water-sealed hood through the counterbalanced swing door.

In operating the furnace, a pan filled with material to be treated is placed on the runway in front of the pusher. The small hand lever near the top of the furnace frame operates the clutch on the motor-driven winch on top of the furnace. The first movement of the cylinder raises both doors enough to admit the pans, which are 3 in. high; a stop on the cable holds the doors at this height while the pan of fresh material is pushed into the furnace. As the fresh pan enters, the pan at the discharge end is pushed onto a dumping carriage, its own weight automatically tips the pan dumping the contents into a hopper, the lower end of which is submerged in the quenching tank; the annealed material falls into a perforated copper basket, which at intervals is lifted out of the quenching tank. As the pan starts to tilt, the pusher carriage is pulled out of the charging end and the doors are dropped. Thus in this furnace the material is not exposed to the atmosphere at any time after entering until taken cold from the quenching tank. This entirely eliminates the possibility of oxidation as the furnace itself has a reducing atmosphere. A heat balance sheet of this furnace annealing German silver at 1400 deg. Fahr. shows the following:

Heat absorbed by 2000 lbs. of metal, 80 kw.
Heat absorbed by 400 lbs. of steel pans, 28 kw.
Heat lost through walls and doors, 24 kw.

A heat balance sheet of this furnace heating 1500 lb. of steel per hour to 1650 deg. will show the following:

Heat absorbed by 400 lbs. of pans, 34 kw.
Heat absorbed by 1500 lbs. of metal, 127½ kw.
Heat lost through walls and doors, 30 kw.

The advantage of this type of furnace over the non-continuous furnace is a lower labor cost and the fact

that the material when brought to the desired temperature may be more quickly removed, eliminating largely the danger of over-heating, and at the same time allowing the material under treatment to be brought to temperature more gradually.

Automatic Continuous Furnaces

The type of furnace best adapted to heat-treating which requires precision is the automatic continuous type, wherein the material under treatment, when brought to the predetermined temperature, is automatically discharged either into the air or into some quenching medium. This method of operation reduces the human element and the chance of error to a minimum. The only part of the operation dependent on the operator is the placing of the material to be heated on the charging platform. When the material at the discharge end of the furnace reaches the maximum temperature, a special pyrometer closes an electrical circuit, which in turn closes, through a suitable relay, the solenoid operated radial dial switch; the various electrical circuits in turn operate the doors, pusher and quenching apparatus.

A typical two-furnace equipment of this type having three operations, heating above the critical point, quenching and re-heating for drawing, consists of the following parts: Two furnaces, a quenching tank, a quenching machine, a control pulpit and two contact-making pyrometers. As all the motions of the equipment are controlled from one radial dial switch, the equipment, when once adjusted, is so interlocked that no material can get through the furnace unless it is first heated to the exact temperature (a maximum of 5 deg. Fahr. is allowed). Immediately upon reaching this temperature it is quenched and allowed to remain in the quenching bath a stipulated time; at the end of this time it is withdrawn from the bath and placed on the charging platform of the drawing furnace. When the material at the discharge end of the drawing furnace reaches the desired temperature, the pyrometer of this furnace sets in operation the operating mechanism, pushing into the furnace the material just brought out of the quenching bath and at the same time discharging the material that has come to temperature.

It is only by this automatic method that the highest class of work in heat-treating can be done, as the only part of the operation depending on the human factor is, as mentioned above, the placing of the material to be heated on the charging platform of the first furnace.

The greatest feature and one that cannot be emphasized too greatly is that when the material is delivered at the discharge end of the equipment it has received the treatment as per the setting of the control equipment, and nothing else. The greatest objection to heat-treatment as generally practiced to-day with combustion furnaces is due to the inability to obtain duplicate results. The automatic equipment just described eliminates the uncertainties of non-automatic equipments and enables heat-treating to be done with as great a precision as it is possible to measure. While with hand operation it is possible to obtain excellent results in actual practice at times, a considerable portion of the material treated will fall below the standard as determined by physical tests. The automatic equipment gives every piece exactly the same treatment.

A tabulation of the results that may be obtained with costs of such a treatment as has just been described is given in Table 7:

It will thus be seen that for a comparatively small cost, steel of much better physical qualities is obtained.

Table VII

Carbon per cent	Treated or Untreated	Ultimate Strength	Elastic Limit	Elongation	Reduction in Area	Per Ton Cost of Electric Heat Treatment Current at ½c per Kw.-Hr.	Increase in Ultimate Strength	Increase in Elastic Limit	Increase in Cost for Heat Treating Steel Costing $30 per Ton
0.25	Untreated	73,000	29,000	24	50	.....	.....	.....	.....
0.25	Treated	112,000	70,000	10	50	$1.50	53%	140%	5%
0.45	Untreated	92,000	36,000	18	42	.....	.....	.....	.....
0.45	Treated	155,000	92,000	10	55	1.50	68%	153%	5%
0.65	Untreated	121,000	40,000	10	24	.....	.....	.....	.....
0.65	Treated	169,000	115,000	7	34	1.50	40%	188%	5%

Treatment consisting of heating to 850 deg. C., quenching in water, reheating to 550 deg. C.

Data taken from Harbord & Hall.

Conclusion

In conclusion it may be stated that the small electric re-heating furnaces are commercially feasible from a fuel standpoint alone, where the current consumption per ton is 400 kw.-hr. and the rate is 1 cent per kilowatt-hour, compared with oil where the consumption per ton is 100 gal. at a cost of 4 cents per gallon, or natural gas where the consumption per ton is 12,000 cu. ft. at 33 cents per 1000 cu. ft. With an allowance made for the saving of metal due to absence of scaling in the electric furnace, the saving in heating cost per ton on the above will be that percentage of saving multiplied by the cost of steel per ton; as, for instance, 5 per cent saving on an automobile steel worth $50 per ton, or a net saving of $2.50 per ton of metal heated. On this basis of metal saving and with a consumption of 100 gal. of fuel oil per ton, in order to compete with electricity at 1 cent, oil would have to cost not to exceed 1½ cents per gallon, or with oil at 3 cents the fuel consumption would have to be under 50 gal. per ton.

Electric furnaces of the continuous type of 5 tons per hour capacity will show commercial economy over coal-fired furnaces of the same capacity which require 200 lb. of coal per ton of steel, with coal at $2 per ton, while the electric furnace requires an electric current consumption of 250 kw.-hr. per ton, current at ½ cent per kilowatt-hour, with a metal saving of 3 per cent over coal-firing, heating a steel worth $35 per ton.

The further advantage of electric furnaces will be, evenness in temperature throughout the billet, and uniformity of temperature one billet with another.

The combination gas and electric furnace will show commercial efficiency compared with producer-gas-fired furnaces using 200 lb. of $2 coal per ton, while the combination gas and electric furnace uses 100 lb. of coal per ton of metal for heating to 1400 deg. Fahr., and 100 kw.-hr. per ton in heating from 1400 deg. to 2000 deg., current at ½ cent per kilowatt-hour, coal at $2, and with a metal savings of 2 per cent on steel valued at $20 per ton.

In the case of soaking pits, the advantage in favor of electric pits is more marked in the way of commercial saving than any of the other electric heating furnaces mentioned, on account of the elimination of the usual metal loss by oxidation of 2 per cent which occurs in producer-gas-fired pits. With steel valued at $20 this item alone is 40 cents per ton. To this add a fuel cost of 5 cents per ton, making a total cost of 45 cents per ton of ingots soaked in producer-gas-fired pits. Electric soaking would cost only 10 cents per ton, current consumption being 20 kw.-hr. per ton of ingots, and the current at ½ cent per kilowatt-hour. This would mean a saving of 35 cents per ton over the prevailing method of operation, besides giving the additional advantage of saving in space, and ingots with surfaces as clean as when charged into the pit.

In heat-treating, the saving in operating cost of electric furnaces over combustion furnaces in most cases

must come in the elimination of oxidation, as, for instance, on high-grade steel, brass and non-ferrous metals, eliminating large expense in acid, and in labor for the pickling operation. In addition to this, the advantage which outweighs, perhaps, all others is the precision with which electric heat-treating may be done. It is obvious that it is useless to heat-treat a series of parts that may go to make up a steel structure, as a bridge, a line of rails, or a set of springs or axles of a locomotive, if the method of heat-treatment is such that dependence cannot be fully made on the gain in physical properties. The failure of a single member of the bridge or a single rail or a spring or axle is almost certain to cause a catastrophe, hence without absolute precision in temperature and method for producing that temperature in every piece alike vital parts of a structure or a machine must be figured on the basis of untreated parts, necessitating a greatly increased weight over that of a design relying on the greater strength of heat-treated parts.

The automatic electric furnaces described above give this precision, and when the material to be treated has come through the furnace it is certain that it has had the prescribed treatment, and nothing else.

The user of steel to-day is willing to pay the additional cost for the additional physical qualities to be obtained by proper heat-treatment, but he has never been willing and never will be willing to pay for the so-called heat-treatment that has in too many cases consisted of simply putting the material through a furnace. Physical qualities of the highest character have been obtained from time to time by treatment in combustion furnaces, but it is almost impossible to obtain duplicate results from day to day, owing to the many variables, including the greatest of all, the human element. The automatic electric furnace requires the minimum of attention in its regulation, and the human element is eliminated completely in the cycle of operation, excepting in placing the material on the charging platform of the furnace.

When the engineer realizes that for an additional cost of from $2 to $3 per ton he can with certainty get the full value of results possible with heat-treatment, the demand for heat-treated material will be a great many times larger than it is to-day.

Electric furnaces have come to stay, and while in the past a great deal of bad steel has been made in all classes of electric furnaces, it must be realized that the same sort of operators would probably have made a great deal worse steel in any other kind of furnace. The application of electric furnaces in melting and refining, and in heating and heat-treating, has only begun, and while the total current now used in this country in electric steel furnaces is only a few thousand kilowatts at this time, within the next ten years it should be several hundred thousand kilowatts. With the growth of electric furnace loads, with their high-load factor and power-factor, the cost of current per kilowatt-hour will be materially reduced, so that even electric smelting, when the high quality of pig iron thus produced is taken into consideration, may become, even in this district, commercially feasible for the better grades of iron to be used in the manufacture of high-grade steels, while electric furnaces for heat-treating, re-heating and the soaking of ingots will have come to hold the same relation and importance in industrial heating operations as the electric motor now holds in the field of industrial power.

* * *

In the extended discussion which followed Mr. Baily's paper, and which is given in full in the April issue of the *Proceedings* of the Engineers' Society of Western Pennsylvania, Dr. C. G. Schluederberg, Mr. Frank Thornton, Jr., Mr. T. D. Lynch, Mr. E. D. Leland and Mr. A. Stucki asked various questions.

Dr. J. W. Richards said for the sake of heat insulation that kieselguhr bricks should be used next the shell or casing, and the latter should be of a polished white metal, such as Monel metal.

Mr. William Hoopes said that "the Aluminum Company of America has lately installed one of the Baily furnaces, and it works. . . . This type of furnace is more flexible than any other type of furnace, i.e., the resistance type of furnace is capable of a more general application. It can be built in almost any size, and the resistance material is cheap and easily used."

With respect to the cost of electrical energy at ½ cent per kilowatt-hour, Mr. Baily said he thought that this "in large capacities includes all the charges, for instance, the investment charge as well as fuel. We have some furnaces now in operation that are operating under 2/3 cent per kilowatt-hour. This is from a central station, of course."

Prof. S. L. Goodale referred to a peculiar point which had come to his attention in heat-treatment experiments, from which it would seem to have been better to have an oxide scale formed than not. "I cannot say the effect is always found, but it certainly happens at times that when no oxide scale is formed the metal itself is decarbonized to a slight extent on the surface, resulting in a soft skin."

In reply to questions of Mr. Thomas S. Perkins on the cost of electrodes and maintenance cost, Mr. Baily said that "a typical furnace, 200 kw., has had two $4 electrodes, and in the way of repairs to brickwork has had about twelve silica brick. It has run about 6000 hours. By a little carelessness the electrodes burned off owing to the resistor material over the electrodes becoming too thin.

"As to the adjustment of the control of the furnace, this will not need any changing for over a period of eight to ten hours or longer; the quantity of material going through the furnace is practically constant. If you have a lower capacity you have to reduce the flow of current into the furnace or the temperature of the furnace will, of course, increase. As to the voltage, take a forging furnace of 250 lb. per hour capacity, the voltage would be about 60 across the furnace. In a furnace of 600-kw. capacity, probably 18 ft. long, the voltage would be about 250. In some cases the two cores of the heat-treating furnace are run in parallel, thus doubling the voltage, cutting the amperage and cables in two by that method.

"The cost of the furnaces themselves will be roughly four or five times the cost of a combustion furnace of the same capacity. Take a typical forging furnace handling 250 lb. per hour would cost about $1,200. A heat-treating furnace of 600-lb. capacity per hour would cost about $2,500. A furnace of 2000-kw. capacity runs about $25,000. These figures may be taken as typical for standard designs. . . .

"The control is obtained through special transformers called regulating transformers, controlling by special switches connected to the special taps of either the primary or secondary of the transformers. If we have to handle a primary voltage of 22,000 we control on the low-tension side. If we have a primary of only 440 volts we control on the high-tension side. All these furnaces are alternating-current furnaces. It is possible to use direct current, but in order to get voltage control a motor-generator set is required."

Single-phase furnaces are usually cheaper to build than two or three phase. A furnace of considerable size, say 1000 kw., would probably be built two-phase.

The voltage depends on the particular furnace, the highest used by Mr. Baily in an actual furnace is 400 volts. Above that there is danger of trouble with electric insulation.

Mr. Baily concluded his reply as follows: "The highest temperature we have ever operated furnaces at is 2700 deg. Fahr., and those furnaces run as long as three weeks without any repairs. At that time they required new linings, which cost about $4.00 and take half a day to renew, counting the time of cooling the furnace down.

"I think I have answered most of the questions that have been mentioned here. Some one has mentioned metal resistors. These seem to be quite feasible for temperatures up to 1500 deg. Fahr. About 2000 deg. they seem to go to pieces pretty rapidly, and are not really commercial at that temperature.

"The upkeep of the furnaces was asked for. We have recently put in operation some furnaces where the upkeep, renewals, etc., were guaranteed to be within 10 cents per ton of metal heated. That is a heat-treating operation. In small forging furnaces the cost will probably run as high as 50 cents a ton, using regular forging furnaces with ruling temperatures of the metal of 2300 deg. Fahr. in the small furnaces. The larger the furnace the less the cost per ton."

The Current Status of the Borax Industry

BY SAMUEL H. DOLBEAR.

The effect of political conditions in Europe has been felt less in the American borax industry than in almost any other branch of the chemical and mineral industry. Possibly this statement would be more clearly correct if it said that the net effect has been a normal production during the past year. On account of depressed business in the United States, local demand has, as a matter of fact, fallen off very considerably. On the other hand European refiners of borax and boracic acid, particularly those of Austria and Germany, have been badly crippled in their operations, and this has resulted in a large increase in American export trade. Canada, which has hitherto been supplied by England, has purchased large quantities from American refiners.

The world's commerce in boron compounds is practically controlled by Borax Consolidated, Limited, an English syndicate with headquarters at London. This company, in addition to its French and English refineries, also has refineries in Austria, and has supplied the German refiners with ore from its Chilean mines.

In Asia Minor the borax mines on the Sea of Marmosa normally produce about 14,000 tons per year. These mines are controlled by the British syndicate and have been for years an important source of ore for French and Austrian refiners. The mines at this point were worked many years before the development of the South American deposits. The participation of Turkey in the war has effectually shut off this source of supply.

In the United States, the mines of California are the only producers of borate ores. The largest production is from the deposits of the Pacific Coast Borax Company, which is now a subsidiary of Borax Consolidated. During the past year this company completed a narrow gage railroad connecting its Biddy McCarthy and Monte Blanco deposits with the Tonapah & Tidewater Railroad at Death Valley Junction. This work represents an expenditure of about $400,000 and opens up some of the best deposits in the Death Valley region. These deposits have hitherto been inaccessible on account of a long rough wagon haul. At Death Valley Junction this company has also built a large roasting plant in which the lower grade ores are calcined before shipment to the refineries.

The Sterling Borax Company, whose mines are located 6 miles from Lang, in Los Angeles County, ranks as second largest producer in California. During 1914 this company is reported to have mined about 15,000 tons of borate ore. This is divided into two grades, the first containing about 31 per cent anhydrous boracic acid; the second about 20 per cent. All of the ore is roasted at the mine before shipment, thereby eliminating impurities which consist of clay, pandermite and water. On roasting, the colemanite content disintegrates into a fine powder, while the pandermite and clay retain their original form. This makes it possible to separate the valuable portion very easily by screening. A branch railroad connects the mine with the Southern Pacific Railroad.

After a period of idleness lasting several years, the Russell Borax Mining Company is again working its mines in the Ventura fields, the control of the company having been acquired by the Stauffer Chemical Company of San Francisco. During the past year fifteen men were employed during the seven months' operating season and a production of 3800 tons was made. The ore mined was colemanite and averaged 37 to 38 per cent A. B. A.

The possibility of the development of an entirely new colemanite field is suggested by the discovery of this mineral in the Kramer section in San Bernadino County. While drilling for water on a ranch four miles from Rich Station on the Santa Fe Railroad, colemanite ore was encountered, the extent of which has been variously reported up to a thickness of forty feet. Little information is yet available regarding this occurrence, but the fact that the land has been purchased by the Pacific Coast Borax Company may be regarded as indicative, in a measure, of its importance.

The borate mines in Chili have been the principal source of this ore for many years, about 75 per cent of the world's supply being normally produced here. Ascotan, near Antofagasta, is the chief producing district. The Chilean mines, as well as those of Peru and Argentine Republic, are controlled by the British syndicate.

It is expected that Peru will become a producer shortly through an arrangement effected by Borax Consolidated with the Peruvian government. This agreement provides for the continuous operation of the mines situated near Arequipa, the construction of reduction furnaces capable of treating 40,000 metric tons annually, and the provision of either a railroad or other transportation facilities.

Although some borates are produced each year in Argentine Republic, none of the product is shipped, and only enough work is done to comply with the mining laws of that country. At Tres Morros the sun dried ore carries about 38 per cent A. B. A., and 1800 tons of such material was produced in 1913. The expense of production is high on account of the scarcity of fuel and distance from rail or water. It is not likely that borates from this country will be produced commercially until cheaper sources have been exhausted.

Borax prices are somewhat higher now than before the war. During the past year quotations for carload lots were at 4 to 4¼ cents per pound as compared to 3¾ to 4 cents in 1913.

Practically all of the borax and boracic acid consumed in the United States is refined in this country. Refineries are located at Bayonne, N. J.; Brooklyn, N. Y.; New Brighton, Pa.; Chicago, Ill., and San Francisco. The product of the San Francisco refineries is sold largely to Pacific Coast and Japanese consumers.

The Electric Furnace in the Foundry*

BY WILLIAM G. KRANZ.

The increased service demands on some of the products of the National Malleable Castings Company prompted it about eight years ago to investigate the electric furnace, both in America and in Europe. The process had already been sufficiently developed in Europe to lead us to believe that the electric furnace would most nearly meet our requirements.

After further investigation and consultation with the highest authorities on the subject, we decided upon the Heroult type as the simplest and most practicable.

In 1910, we built a furnace of this type, of 300 lb. capacity, for experimental purposes, and although it was crudely constructed the quality of the material we were able to make justified the installation of a 6-ton Heroult furnace in 1912.

This furnace has three electrodes, 17 in. in diameter, uses three-phase, 60-cycle current, and is equipped with Thury regulators, which give us good regulation and a uniform load on the line even when cold melting. The power factor of the furnace is 94 per cent.

Since July, 1912, the furnace has been in continuous operation, producing up to the present time over 20,000 tons of both carbon and alloy steels of varying analyses and of exceptional quality. Both cold and hot-metal charges have been used, with a power consumption of about 150 kw.-hr. per ton in the case of hot-metal charges and from 500 to 600 kw.-hr. per ton in the case of cold charges.

The electric energy consumed varies according to the final analysis of the steel and the amount of refining required. Too much cannot be said about the refining possibilities of the electric furnace, for no other method of steel manufacture can compete with the electric in this respect.

In proper operation lies the whole secret of success. That steel has been made electrically means nothing, for when the furnace is operated under oxidizing conditions the quality is no better than that of open-hearth material; but when properly made, electric steel is as good as that made in the crucible, and very much less expensive. The operation of the furnace is simple and the resultant composition is scientifically accurate. I might cite an example in this connection:

On a heat of steel treated under a slag of high-silica content some metallic aluminum was added in order to reduce the silicon from the slag in accordance with the following chemical equation: $3SiO_2 + 4Al = 3Si + 2Al_2O_3$. Analysis showed that the amount reduced was theoretically correct according to this equation.

The most important of the many advantages of electric steel castings over those made by the ordinary processes are briefly summarized below, and it should be kept in mind that these apply not only to carbon steels but to the alloy steels as well.

1. Absence of segregation, elimination of oxides, and absolute uniformity of composition regardless of atmospheric conditions which affect open-hearth furnaces.

2. Almost entire elimination of sulphur is possible (an important consideration in steel castings) and complete control of the other elements.

3. Great tenacity, giving ability to withstand much more abuse and fatigue without rupture.

4. High ratio of elastic limit to ultimate strength.

5. A more ready response to heat treatment and with much more uniform results.

6. Perfect control of pouring temperature, combined with ability to obtain very hot metal, so that light and intricate shapes are readily cast.

Let us take up the advantages of the more important of these qualities of electric steel, and investigate them more fully.

First.—Absence of segregation and oxides has been firmly established by a great many investigations in our chemical and microscopical laboratories. As a more practical proof of the elimination of oxides, we know that additions of any of the ferro-alloys to the bath will be found alloyed with the steel in their theoretical amounts. This is even the case with elements, such as aluminium and titanium, which are so susceptible to oxidation, proving conclusively in our minds that there could be no oxygen present in the steel. Leading authorities have agreed for some time that the electric steel furnace is the one means of preventing segregation.

W. R. Walker, in May, 1912, read a paper on "Electric Steel Rails" before the American Iron and Steel Institute, in which he stated that "Ingots of even eight tons had been produced electrically which were practically free from segregation."

Second.—We know of no authority who doubts the practical elimination of sulphur in electric-furnace operation. We have repeatedly reduced the sulphur to a trace in irons containing as high as 0.30 sulphur. The rapidity with which this reduction takes place depends somewhat upon the carbon content of the material, the sulphur reducing very much more rapidly in the higher carbon materials.

Third.—To illustrate the great tenacity of electric steel we submit (Fig. 1) exact reproductions (reduced) from two tests of two similarly treated specimens of steel, which are typical of a large number made on an Upton-Lewis toughness testing machine. One of these is electric and the other open-hearth, of almost identical analysis, as shown below. The marked superiority of the electric steel specimen, especially as to its tenacity, is shown in Table I.

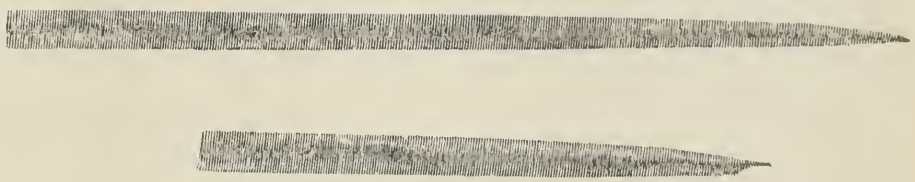


FIG. 1—TESTS WITH BASIC OPEN-HEARTH STEEL, ANNEALED, 213 CYCLES (UPPER PICTURE) AND ELECTRIC STEEL, ANNEALED, 345 CYCLES (LOWER PICTURE)

Table I.—Comparative Properties of Electric Steel and Basic Open-Hearth Steel.

Electric Steel.

C, 0.24; Mn, 0.52; Si, 0.25; P, 0.010; S, 0.019.

Elastic limit	36,400 lb.
Ultimate strength	65,300 lb.
Elongation	36 per cent
Reduction	55 per cent
Toughness test (fatigue) to break	345 cycles

Basic Open-Hearth Steel.

C, 0.23; Mn, 0.53; Si, 0.24; P, 0.011; S, 0.038.

Elastic limit	34,800 lb.
Ultimate strength	63,000 lb.
Elongation	29½ per cent
Reduction	35 per cent
Toughness test (fatigue) to break	213 cycles

*A paper to be presented at the San Francisco meeting of the American Institute of Mining Engineers.

Fourth.—During the past year we have developed an electric steel having remarkable physical qualities after heat treatment. This was accomplished without resorting to any of the high-priced alloys. The steel, when subjected to shock or static pull, will stand from four to five times as much stress without distortion as the ordinary open-hearth product. This assertion is not based on a few tests, but on over 3000 made up to the present time.

We have made a great many similar tests of heat-treated open-hearth material, and have invariably found that in certain specimens the physical properties are impaired by the treatment rather than benefited. This is not, however, the case with the electric-furnace product. The old saying: "In order to make good bread you must start with good dough," we believe applies to the steel industry as well.

CONCLUSIONS

The greatest advantage of the electric-furnace process over all others is its uniformity of product. The open-hearth under certain conditions will, we know, produce steel of very good quality, but there are so many contingencies, such as atmospheric conditions, stack-draft, fuel and furnace variations, beyond the control of the operator, that absolutely uniform results are impossible.

Electric-furnace products are looked upon by some with skepticism, due to those who have adopted the process thinking it a panacea for all of their ills, and who have furnished the trade with products not worthy the name. The lack of knowledge and the inexperience of the operator should in no way condemn the process. The production of perfect castings does not entirely depend upon the quality of material of which they are made, but upon the foundry practice to a very great extent. Frequently excellent material is ruined by bad foundry practice. Nevertheless we feel that the electric furnace, with its perfect control of composition and temperature, fills a long-felt want in the industry.

National Malleable Castings Co.,
Sharon, Pa.

Synopsis of Recent Chemical and Metallurgical Literature

Crushing and Grinding

Hardinge Mill Data.—In a paper to be presented by Mr. A. F. Taggart at the San Francisco meeting of the A. I. M. E. in September, the author presents numerous data on Hardinge mill operation at different plants, and gives a summary, as follows:

	6 ft. by 16 in. Ball Mill	8 ft. by 22 in. Pebble Mill
Average maximum size of feed, mm	44.5	9.7
Average size of feed, mm	9.0	1.26
Average maximum size of product, mm	6.0	1.5
Average size of product, mm	0.37	0.14
Average per cent of—200 mesh in product	28.9	37.0
Average per cent of—200 mesh in product, no slope	.....	44.3
Average per cent of—200 mesh in product, 0.5 to 4 in. slope	.....	31.6
Reduction ratio, range	7 to 67	6 to 15
Reduction ratio, average	39.6	8
Average size of product, no slope, mm	.....	0.10
Average size of product, slope 0.5 to 4 in.	.....	0.17
Average tonnage	203	110
Average tonnage at no slope	.....	85
Average tonnage at 0.5 to 4 in. slope	.....	128
Average horsepower	35.06	35.6
Average charge, balls or pebbles, tons	4	4.5
Average ball or pebble consumption, pounds per ton	0.51	1.94
Average relative mechanical efficiency	53.2	20.5
Average percentage of water in feed	60	58.7
Average revolutions per minute	28	27.8

Gold

Gold Refining with an Electric Furnace.—At the Alaska-Treadwell cyanide plant an electric furnace has been substituted for a blast furnace for treating the by-products from the Tavener refining process. The by-products consist of slag, matte, flue-dust and refinery refuse. The operation is described by Mr. W. P. Lass in a paper to be read at the meeting of the A. I. M. E. in San Francisco next September.

A sectional view of the furnace is shown in Fig. 1. The body of the furnace was constructed from an old steel drum by cutting off the top and introducing a cable, made from strands of bare copper wire, through the bottom and spreading the strands out fan-shaped on the inside of the drum.

Powdered graphite, obtained by grinding up old crucibles, mixed with 10 per cent cement, was tamped wet into the bottom of the drum, around and completely covering the copper wires. The graphite was carried up to the bottom of the furnace, or lead-well, and acted as the lower electrode. The sides were built up of ordinary firebrick forming a melting chamber 14 in. in diameter by 20 in. high.

The upper electrodes, of graphite or carbon, are 3 in. in diameter and 40 in. long, arranged with joints enabling new electrodes to be connected without shutting down or wasting stubs. A screw feed was arranged for raising and lowering the upper electrode.

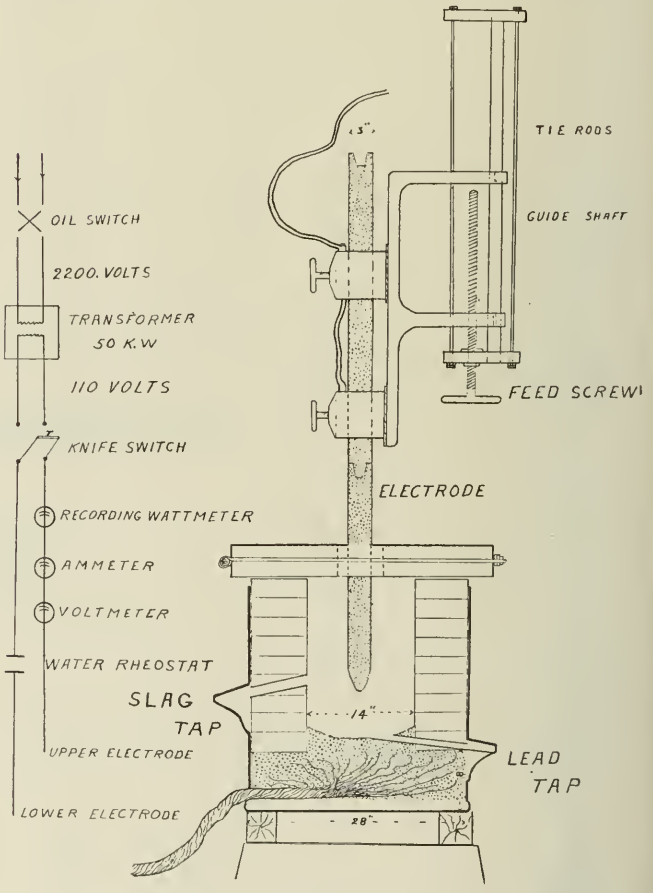


FIG. 1—SECTIONAL VIEW OF ELECTRIC FURNACE

The cover for the furnace had three openings, one for feeding the charge, one for the escape of gases, and one in the center for the introduction of the electrode. It was later found more practical to enlarge this center opening to 6 in. in diameter, to allow of a central feeding of the charge around the electrode.

A 4-in. pipe connected to a ventilating fan carries off the escaping gases.

The furnace is operated on the lighting circuit through a 50-kw. transformer, 60 cycles, 110 volts.

Later, a water rheostat, operated by raising and lowering one disk on another submerged in a barrel of water, was constructed to lower the voltage for use

when starting the furnace, or when there was a bath of metal in the bottom of the furnace that would otherwise allow too much current to pass and thereby cause short circuiting.

The material to be treated in the furnace is mixed in the following proportions: Refinery by-products, 100 lb.; old reverberatory hearths, containing 60 per cent CaO, 20 lb.; litharge, 20 lb.; coke, 2 lb.; scrap iron, 3 lb. About 160 lb. of the mixture is added for a charge. The total amount of material added during the melt is 8507 lb., of which 5870 lb. is by-product material (old slag, the residue from burning old mill launders, sweepings, etc.) of the following composition:

	Per Cent
SiO_2	40.1
Fe	16.0
CaO	16.1
Cu	5.9
Pb	3.0
Zn	5.7
Al_2O_3	2.0
S	3.6
Moisture	1.0
	96.4
Gold	$1,096.60 per ton

Coke is added to the charge as a reducing agent, only a quantity sufficient to throw down the lead being used.

The charge is introduced into the top of the furnace through the central opening around the electrode without removing the slab cover.

In starting, the furnace is operated as an arc furnace, until it has become thoroughly hot, when the charge, consisting of slag, brick dust, etc., is added, the electrodes being raised as the load in amperes increases, until the entire chamber is filled with the charge and the upper electrode extends into the melt almost a foot. As the charge continues to melt the electrode is moved down or up, keeping the amperage reading as nearly constant as possible. The raising or lowering of the upper electrode decreases or increases the power consumption and thereby affects the amount of heat generated.

At this stage the furnace is no longer operating as a simple arc furnace, but has automatically transformed itself into a resistance type of furnace, the semi-fluid or molten charge acting as the resistor, the current passing from one electrode through the center of the charge to the other.

After the charge is in quiet fusion, which takes on an average 2 hr. 10 min., the power is turned off and the charge allowed to settle for 15 min. before tapping the slag. This allows the lead to settle out, the furnace acting as a forehearth.

In operation, the molten lead and slag are tapped, as in the blast furnace. If the lead freezes it is melted by diverting current from the upper electrode and letting it pass through the lead, the tapping rod playing as an arc on the side of the furnace or into the lead tap.

The operators use colored or amber glasses to protect their eyes from the glare of the electric arc.

Operating Data	
Total running time	128 hr. 40 min.
Average weight of charge added	160.5
Average fusion time of charge	2 hr. 25 min.
Total number of charges	53
Graphite electrodes used	1 per 24 hr.
Total power for 128 hr. 40 min., kilowatt-hours	4,440
Power used per hour, kilowatts	34.50
Power used per pound of material fed, kilowatt-hours	0.52
Power used per ton of material fed, kilowatt-hours	1,044.0
Acheson graphite used per hour, feet	0.15
Material melted per hour, pounds	67.7
Material melted for 24-hr., pounds	1,625.0

The only item of cost for flux is the coke, 2 lb. per 100 lb. of by-product material or 118 lb. total being used, since the old reverberatory hearths furnish the lime; the cupels from bullion refining, the litharge, and mill scrap, the iron.

Both graphite and carbon electrodes are used, the former costing $2.95 each, and the latter $1.20. Power cost is less than 1c. per killowatt-hour.

The labor required for the operation of the furnace, including the work of charging and tapping, is one-half one man's time, when melting 1 ton in 24 hr.

The furnace was constructed and put into operation by the regular cyanide-plant crew, without the aid of special electricians. The operation is so simple as to require no special training. Although the operators were unaccustomed to handling electrical equipment, no trouble has been experienced from electrical shocks, since the bottom of the furnace acts as the lower electrode, or grounded circuit.

The advantages of the electric furnace compared to the blast furnace for melting high-grade gold slags are: A saving in mechanical loss of gold in flue dust, because the melting is done in a quiet neutral atmosphere, instead of in a rising blast of air; the obtaining of a lower-grade slag, free from shot, by reason of the quieter melting action and the higher temperature obtainable, making a more fluid slag; the nicety of regulation of the melting temperature; the benefit to the general health of the operators.

Chemical Engineering

Hydrogen Manufacture.—In an article on the manuture of hydrogen for the inflation of baloons, in *Revue générale des Sciences* of June 15, 1915, Mr. A. FOURNIOLS gives a history of the development of hydrogen-generating processes and describes some methods of producing this gas for inflating purposes.

The problem of transportation presented the greatest difficulties in connection with the utilization of the hydrogen gas set free in large quantities as a by-product in electrolytic, caustic and chlorine plants. In compressing and transporting this hydrogen a problem presented itself in the great weight which must be moved to get a small amount of hydrogen to a certain point. This gave rise to the development of other processes in which not the hydrogen but the apparatus and material for its production were placed on carriages. A few of these processes are the hydrolitic or calcium hydride process, the silicon and ferro-silicon process, and the coke and oil process used in Germany. The calcium hydride process depends upon the reaction $CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2$. The apparatus consists of a generator, water reservoir, purifier, and various other minor attachments, mounted on a carriage. A comparison of the price of transporting gas in this way with the compressed hydrogen method follows (1 franc = about 20 cents):

Cylinders with Compressed Hydrogen	Francs	Hydrolytic	Francs
8000 tubes at 80 fr.	640,000	48 tons at 5 fr. per kg.	240,000
50,000 cubic meters of hydrogen at 0.40 fr.	20,000	Apparatus for generating	40,000
Carriers for tubes	60,000	Carriers for reagents	4,000
12 carriages of 3 tons	240,000	2 carriages of 3 tons	40,000
	960,000		324,000

This table is only intended to compare transportation cost, as the hydrolytic process is expensive as a stationary means of production.

The silicon process consists in decomposing a compound of silicon by a concentrated soda solution. The apparatus required is a generator containing the soda, a spraying apparatus containing ferrosilicon, a washer and dryer for the gas. The standard stationary apparatus furnishes 1500 cubic meters per hour, while the movable apparatus, using two wagons, furnishes only 400 cubic meters per hour. The latest German process used for both lighting and inflating purposes, using coke and oil, is also capable of being transported ready for generating purposes. For a description of this process and other information on hydrogen production see this journal, Vol. IX, page 157.

Glass Melting.—Methods of manufacturing glass, descriptions of furnaces and the properties of glass in the molten condition are discussed in an article by Hugo Knoblauch, in *Zeitschrift für angewandte Chemie*, June 22, 1915. The characteristics of molten glass mixtures are illustrated by drawings of cross-sections of crucibles containing characteristic charges. The fact that the temperature at which our very best fireproof clay weakens lies near the temperature needed to produce a good melt is shown to make the pyrometer very useful in glass making.

Investigation of Fusible Tin Boiler Plugs.—The failure and deterioriation of fusible tin boiler plugs in service has been investigated by G. K. Burgess and P. D. Merica of the Bureau of Standards. The complete investigation will be published in a Bulletin shortly to be issued by the Bureau of Standards. In some cases such plugs have failed to melt and so give warning of dangerous boiler conditions, and investigation has shown that the tin filling in these cases had become oxidized to tin oxide (SnO_2), which has a melting point above 1600 deg. C. (2900 deg. Fahr.). About 1050 plugs, of which 100 were plugs which had been in service, were obtained through the courtesy of the Steamboat-Inspection Service, Department of Commerce, and subjected to examination. This included inspection of design and construction, condition and purity of the tin filling, and in the case of the used plugs their classification according to the type of deterioration undergone by them in service.

One pronounced and dangerous type of deterioration is the oxidation of the tin along the grain boundaries by which is formed a network of oxide throughout the tin. The plugs showing deterioration of this type all came from the same manufacturer and contained zinc in amounts varying from 0.3 to 4 per cent. It is shown that this type of oxidation is due to the presence of this zinc. The latter metal is not soluble in the solid state in tin, and when a tin with small amounts of zinc is heated as in a boiler to about 180 deg. C (340 deg. Fahr.) this zinc coalesces as a network enveloping the tin crystals or grains. The boiler water, particularly if it contains alkali, will attack the zinc, eating its way into the alloy along the zinc network, and finally form the oxide network described.

Lead and zinc are found to be the principal impurities in tin plug fillings, and since all "failed" plugs contained these or other impurities the conclusion is reached that if these impurities are eliminated by strict specifications and inspection, which will allow only admittedly superior qualities of tin such as Banca and some others, the danger of failures of these plugs will no longer exist. In order to test quickly the purity of a tin sample a determination of its freezing point may be made. This can be done conveniently with two or three grams of the sample, and requires only inexpensive apparatus, including a high resistance millivoltmeter and a copper-constantan thermo-couple.

Electroanalysis and Electrodeposition

Procedure in Electroanalysis.—Two papers by E. P. Schoch presented at the New Orleans meeting of the American Chemical Society are interesting. They are abstracted in *Science* of July 16. The first of these, a paper by E. P. Schoch and Denton J. Brown, deals with a "systematic, rapid, electroanalytical procedure for the separation and determination of silver, arsenic, copper, bismuth, antimony, tin, lead, and cadmium.

In earlier work the authors have shown that copper, tin, lead, bismuth, and antimony can be determined accurately by electrodeposition out of acidified chloride electrolytes which contain suitable reducing agents such as hydroxylamine or formalin. They have found since that copper, bismuth, and antimony can be deposited simultaneously, and can be separated from tin and lead; that tin and lead can be deposited simultaneously and separated from cadmium; that copper or bismuth can be separated from antimony by dissolving alloys of these metals in nitric acid plus tartaric acid and electrolyzing the solutions with a limited cathode potential; that bismuth phosphate can be precipitated quantitatively out of the same solution; that tin may be separated completely from lead by dissolving an alloy of these two metals in nitric acid plus potassium nitrate, and that silver in silver chloride may be determined by dissolving the latter in ammonia, adding ammonium nitrate and electrolyzing.

These facts are all combined in the following systematic procedure for the rapid electroanalytical determination of all the common metals the potentials of which are more noble than that of cadmium.

(A) Dissolve sample in hydrochloric acid or in aqua regia; an insoluble residue—silver chloride—is dissolved in ammonia plus ammonium nitrate, and the silver determined electrolytically.

(B) Treat solution A with hydroxylamine—mercury, gold and platinum will be precipitated and can be determined by well-known methods.

(C) Out of filtrate B remove arsenic by distillation with hydrochloric acid, and determine arsenic iodometrically.

(D) Electrolyze retort residue C—copper, antimony and bismuth will be deposited with a cathode potential limited to 0.45 volts (against the normal calomel electrode).

(E) Dissolve metal deposit B in nitric acid plus tartaric acid, and precipitate bismuth as bismuth phosphate.

(F) Electrolyze filtrate E with a limited cathode potential—copper alone will be deposited. Antimony is obtained by difference.

(G) Electrolyze residue D with a cathode potential limited to 0.7 volt against the normal calomel electrode —tin and lead will be deposited. Treat the deposit with nitric acid plus potassium nitrate; the solution contains all the lead, and this metal may be deposited as lead peroxide, or the residue of tin oxide may be dissolved in hydrochloric acid plus hydroxylamine and the tin determined by electrolysis.

(H) Electrolyze residue G to obtain cadmium or other metals.

The second paper, by E. P. Schoch and W. A. Felsing, deals with the influence of the potassium ion upon the **potential of the ferrocyanide-ferricyanide electrode.**

The potential of the ferrocyanide-ferricyanide electrode is made more noble by the addition of potassium salts to the electrolyte, but the amount of this change in potential is much greater than the amount calculated from the change in the ratio of ferrocyanide to ferricyanide ions when the concentrations of the latter are calculated from the conductivity ratio and with the aid of the rule of mixtures as set forth by Sherrill. It was suggested by Lewis that this extra effect may be due to the potassium ion taking part in the pole reaction. Thus, with the undissociated salts, the reaction would be $K_3Fe(CN)_6$ plus K-ion plus one electron gives $K_4Fe(CN)_6$, and it has been shown recently by Mueller that with concentrations of potassium ion ranging from 0.2 normal to 0.8 normal the amount of change in potential corresponds to the amount of change in the potassium ion if the concentration relations of the other substances remain constant. Since the latter is not likely to be true, and since the potassium ion shows the

same influence even in the most dilute solutions tried, the authors sought to ascertain whether or not concentration influence of the potassium ion is constant with a particular power of its concentration. This was found to be the case with the 0.75 power of the potassium ion concentration, and if the ferrocyanide and the ferricyanide ion concentrations are calculated from the conductivity ratio and the rule of mixtures. The various mixtures tried present a range of total potassium ion concentration from 7.8 millimol to 395 millimol per liter. In some mixtures the potassium ion was derived wholly from the iron cyanides, in others almost wholly from potassium chloride, and in others still partly from both sources. The different potentials thus reduced to unit concentrations present a maximum range of 8 millivolts with this large variation of concentrations, and hence the result may be considered to be constant. Furthermore, it is likely that on reptition, measurements will be obtained which will show considerably less variation.

Since the calculation of the above potentials involve the general dilution law of strong electrolytes and the rule of mixtures, it was desirable to test these calculations in some way, hence the conductivities of these mixtures were measured and compared with their calculated values. When allowance is made for the influence of the viscosities of the solutions, then the observed and the calculated conductivities agree to 1 per cent and less.

The work is now being repeated with calcium salts in place of potassium salts. Although the immediate result of this work is the establishing of an empiric relation between concentrations and pole potentials, yet it is likely that the results will throw some light on the manner of ionization of salts with polyvalent ions—particularly because other electrodes, such as the thallous-thallic, the ferrous-ferric and the mercurous-mercuric, show similar relations.

Recent Chemical and Metallurgical Patents

Gold

Vacuum Filter.—A modification of the revolving vacuum filter is shown in Fig. 1, being the patented invention of Mr. HENRY B. FABER of New York City. It consists of a skeleton wheel structure in which are mounted filter pockets 10 which are connected, through a suitable valve in the hub, with a source of vacuum. In operation the wheel is revolved slowly and each pocket

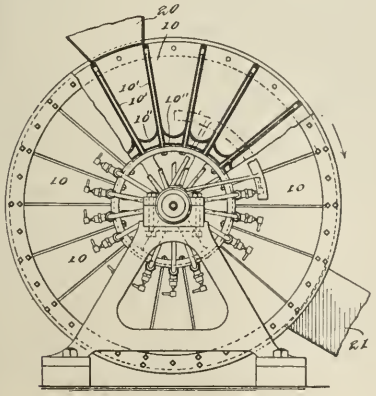


FIG. 1—FILTER

receives a charge from the hopper 20. Being under vacuum, the fluid is withdrawn from the pocket and the solid material forms a cake on the filter surface. As the filter continues to revolve, the cake is discharged by gravity at a predetermined point, as in the hopper 21. As no provision is made for washing the cake, the machine is adapted for use only as a dewaterer and not in cases where complete displacement of the liquor from the solid is required. (1,133,944, March 30, 1915.)

Copper and Zinc

Hydrometallurgy of Copper Ores.—In a patent granted to Mr. N. V. HYBINETTE of Christiansand, Norway, the inventor discloses his process for roasting copper ores and extracting the copper therefrom. An improvement in the ordinary roasting process is claimed in the addition of a quantity of sodium sulphate to the ore. The effect is to form double sulphate of sodium and copper which is decomposed only at temperatures higher than those prevailing in the roasting furnace. The addition of from 2 per cent to 5 per cent sodium sulphate forms a fusible double sulphate which has the property of dissolving sulphides and which forms a spongy mass easily leached with dilute sulphuric acid. The solution resulting from subsequent electrolysis contains sulphuric acid and ferric sulphate and is used for further leaching. Ultimately this solution will contain so much sodium sulphate that it can no longer be used for leaching. When this point has been reached and the solution contains about 450 gr. sodium sulphate per litre, the solution itself is added to the ore in order to supply the sodium sulphate for roasting. The iron salt in solution is decomposed in the roasting furnace, exerting a solvent effect on copper sulphide remaining in the ore as a result of incomplete roasting. (1,140,682, May 25, 1915.)

Electrolysis of Copper Solutions.—In the electrolytic reduction of copper solutions, the presence of certain compounds of metals other than copper exercises a solvent effect on the deposited metal, which is often detrimental. Thus ferric compounds in an electrolyte would act to dissolve deposited copper. Mr. LAWRENCE ADDICKS of Douglas, Ariz., has discovered that the presence in solution of a quantity of aluminum sulphate retards the corrosion rate at the cathode to a small proportion of the quantity of copper deposited per unit of time at the current density used. As a practical illustration of conditions suitable for good work, the inventor gives the following: A solution containing copper, iron and aluminum sulphates, containing 3 per cent copper, 3 per cent ferrous iron and 3 per cent alumina, some free sulphuric acid to prevent the formation of basic salts. This is electrolyzed with a current density of 13.5 amp. per square feet, at a temperature of 115 deg. Fahr., and with a circulation sufficient to keep the average concentration of ferric iron at about 0.25 per cent. Under such conditions a cathode deposit equivalent to from 70 per cent to 90 per cent of the theoretical can be obtained. (1,138,921, May 11, 1915.)

Metallurgical Furnaces

Reducing Aluminium Sulphate to Alumina.—A furnace adapted to the preparation of alumina suitable for electrolytic reduction to aluminium is shown in Fig. 2,

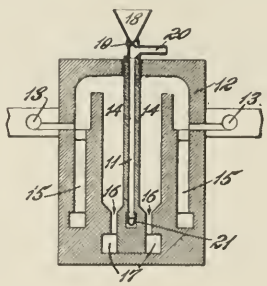


FIG. 2—FURNACE FOR PRODUCING ALUMINA

being the patented invention of Mr. GUSTAVE SCHWAN of St. Louis, Mo. It consists of a retort 11 arranged in a furnace 12. The retort is constructed of refractory material capable of withstanding temperatures up to

1200 deg. C., and is separate from the furnace. Inside measurements of the retort are 8 in. wide and 8 ft. or more in height. The furnace is heated by gas which enters by pipes 13 which convey the gas to the upper portion of the combustion chamber 14. Preheated air is conveyed to the same point by pipes 15. The Products of combustion flow through passages 16 to a flue 17. The material to be treated may be fed into the retort from a hopper 18 by means of a feeding device 19. The gaseous products from the retort pass out through pipe 20, and the solid product is removed by a screw arranged at 21. (1,132,738, March 23, 1915.)

Roasting Furnace.—A method of heating the charge in a roasting furnace of the superposed-hearth type, without subjecting the rabbles to excessive heat, is patented by Mr. Utley Wedge of Ardmore, Pa. Gas, oil or electric current may be used as the heating medium. The rabble arms and means for heating, either oil or gas burners or electric heaters, are all attached to the same central rotating shaft, but are disposed at right angles with each other, so that the rabbles are at some distance on the hearth from the heaters. (1,133,829, March 30, 1915.)

Iron

Process for Dephosphorizing Pig Iron.—According to a method of removing the phosphorous from pig iron, patented by Amand Francois Pasquier of Dijon, France, iron oxide and lime in a finely pulverized condition are blown through the tuyeres by the air blast. The iron oxide is claimed to rapidly transform the phosphorus into phosphoric acid, which combines with the lime and passes into the slag as calcium phosphate. The phosphorus is thus eliminated without the usual overblasting or recarburation. Instead of lime, magnesia, dolomite, or similar bases could be used and the oxide of iron might be added in the form of hammer scale or force scale (1,145,506, July 6, 1915).

Aluminium

Treatment of Surfaces of Aluminium for Plating.—A process for preparing aluminium surfaces for plating is patented by Francois Auguste Roux of Paris, France, and assigned to Société L'Aluminium Français. In this process the aluminium surface is first cleansed by any common method, then it is rinsed and immersed in a dilute acid or alkaline hydrate solution to which 1 per cent of tin chloride is added. This gives a coating of tin on the surface. The surface is then rinsed and immersed into hot saturated solution of ammonia alum. This is claimed to cause any inclosed hydrogen to escape and to prevent the oxidation of aluminium which has been the greatest hindrance to aluminium plating. It also gives tenacity to the tin deposit. The surface is then rinsed and dipped into dilute sulphuric or nitric acid and finally placed in the plating bath (1,140,000, June 22, 1915).

Process of Plating Aluminium.—Another process of plating aluminium is patented by Joseph A. Hall of New Britain, Conn. In this process the aluminium is first cleansed in the usual manner, then given a bright dip in a solution made up of 2 parts nitric acid and 1 part oil of vitriol. This is to remove iron, which is claimed to be found usually on the surface of commercial aluminium and which is believed to hinder successful plating. The surface is then electroplated with zinc for a few seconds and is then ready to receive the plate of brass, copper or silver. In the case of nickel plating a preliminary coating of copper is first given for twenty to thirty minutes and then the nickel is applied. The process is claimed to be particularly applicable to plating the material used for making die castings, which is high in aluminium (1,147,718, July 27, 1915).

Oil

Dehydrating Petroleum Oil.—Apparatus for the separation of water and petroleum oil when mixed in the form of emulsion is described in three patents issued to Robert E. Laird and Joseph H. Raney of Taft, Cal. A general outline of the process is as follows: In the treater, Fig. 3, the emulsion enters at 23 into chamber 16, which surrounds the outer electrodes 21. It is heated here by steam coils to any desired temperature, and then passes through openings 22 into chamber 17, and upwardly between the outer electrodes 21 and inner electrodes 19. When an alternating current is impressed on the electrodes, it tends to change the trapped water into free water and to coalesce the free water. The emulsion flowing upward is fairly free from water at the top and no extra insulation is required at the surface. The freed oil passes upward into pan 12 and down through pipe 231 into another final separator. The electrical apparatus, which is a distinct feature of the invention, consists of a condenser placed across the electrode terminals, and a "distributer" which is so adjusted that only the peaks of the alternating wave are utilized, which during the other parts of each period the current charges the condenser which subsequently discharges through the oil along with the high-voltage current represented by the peaks. This gives maximum power economy. Means are also provided to allow escape of gases and to prevent combustion. The process is described fully in *San Joaquin Light and Power Magazine* for May, 1915, where it is said to be in successful use on the property of the Traders' Oil Company in the Midway Field (1,142,759, 1,142,760 and 1,142,861, June 8, 1915).

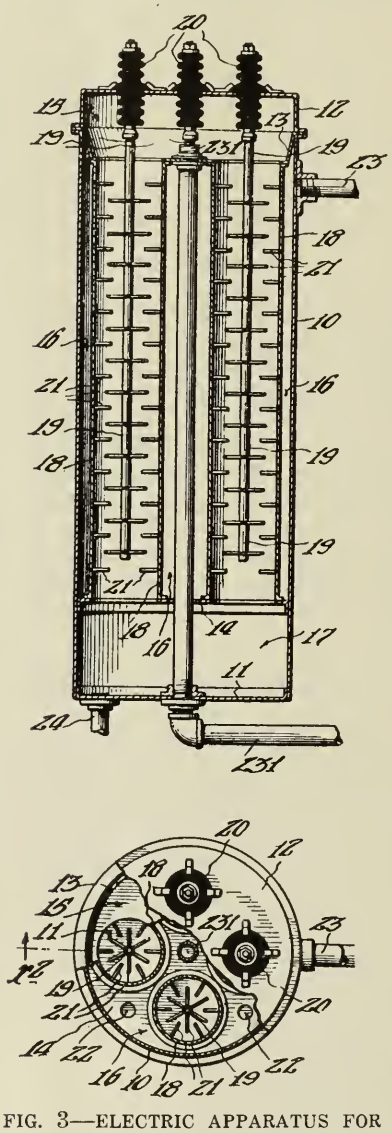


FIG. 3—ELECTRIC APPARATUS FOR DEHYDRATING OIL

An aluminium alloy, patented by Alfred Wilm, of Schlachtensee, near Berlin, Germany, contains about 95.5 per cent aluminium, 0.5 per cent magnesium, 3 per cent copper and 1 per cent manganese.

The inventor claims to have discovered an alloy that retains the advantage of aluminium as to light weight, in addition to other advantages which are not possessed by that metal.

Thus it is claimed that this alloy can be bored, drilled, planed, filed and ground successfully.

Callow Pneumatic Process of Flotation

The diagram, Fig. 1, indicates the various elements which compose the scheme.

A is an agitator operating by compressed air for the purpose of mixing or emulsifying the oil, the air and the water. The same type of apparatus as is in common use in cyanide works. In cases where the oil or frothing agent can be fed into a crushing machine or tube mill, this agitator or Pachuca tank can be dispensed with and the ore fed direct from tube mill into the separatory cell.

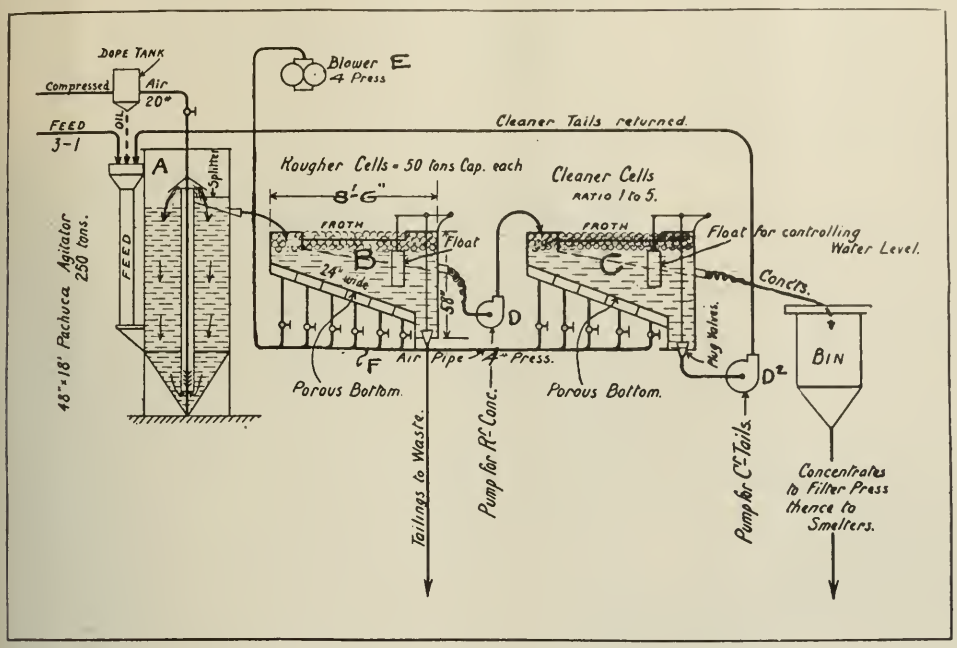


FIG. 1—CALLOW PNEUMATIC FLOTATION PROCESS

Separatory Cell

B is the initial or roughing separatory cell; it consists of a tank about 9 ft. long over all and 24 in. wide, with bottom inclined at from 2 to 3 in. of fall per foot; it is 15 in. deep at the shallow end and 37 in. deep at the deepest end. It may be built of either steel or wood, preferably wood.

The bottom of the tank consists of a porous medium made of four thicknesses of loosely woven canvas-twill properly supported by a backing of perforated metal to prevent its bulging when under air pressure. Through this porous medium, compressed air at from 4 to 6 lb. pressure is forced by the blower *E*. Porous brick or any other ceramic material may be used that will give the necessary fine subdivision to the air. Some of these have been tried out, but for practical and mechanical reasons the loosely woven canvas-twill seems to better serve all purposes than anything else and has been adopted as a standard porous bottom construction.

The space underneath this porous medium or bottom is subdivided into eight compartments, each connected by an individual pipe and valve with the main air pipe *F*. By this means the air pressure to each compartment can be regulated (by throttling the valve) to correspond to the varying hydraulic head within the tank so as to discharge a uniform amount of air throughout the length of the bottom and maintain a uniform agitation of the contents. The amount of air required is from 6 to 8 cu. ft. free air per minute at from 4 to 6 lb. pressure per square foot of porous medium. A 500-ton plant will require about 30 hp. to operate compressor, blower and pumps.

Each longitudinal edge of the tank is provided with a lip and an overflow gutter for the reception of the froth to be discharged. The lower end of the tank is furnished with a spigot discharge fitted with a plug valve, operated by a float, for the purpose of maintaining a uniform water level within the tank and thus in turn maintaining a uniform and constant discharge of froth under all the varying conditions of feed supply incident to practical milling operations. The water level may, of course, be varied, but is usually maintained at about 10 to 12 in. below the level of the overflow lips. The tailings are discharged through the spigot and the frothy concentrates are conveyed by means of the side gutters to the pump *D* and thence to the cleaner separatory cell marked *C*. This cleaner cell is a machine of exactly the same construction as the rougher. In operation, however, it is usually run with a lower air pressure than that used on the rougher; the tailings from the cleaner are pumped by *D*2 back into the original feed and so maintain a closed circuit on this portion of the feed.

The concentrates from the cleaner are the shipping or finished concentrates. Pump *D* can be eliminated if desirable by setting the cleaner at a lower elevation and conveying the rougher froth to it by gravity.

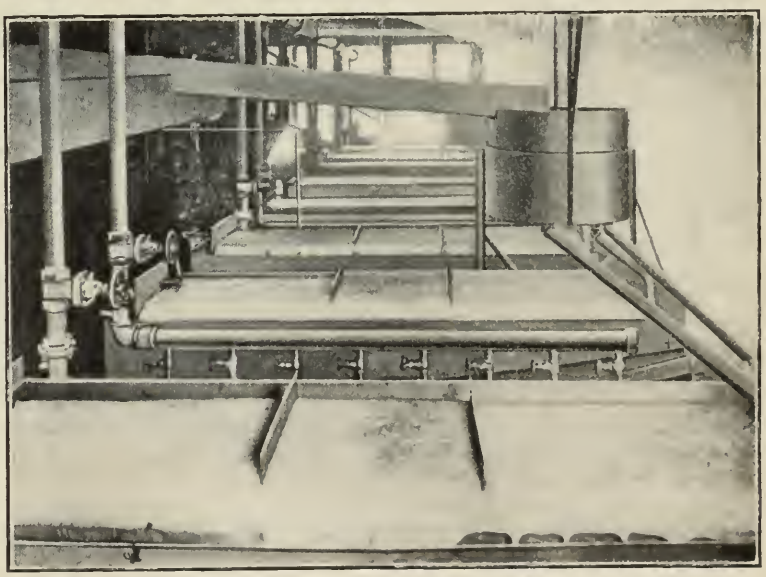


FIG. 2—500-TON INSTALLATION CALLOW PNEUMATIC FLOTATION MACHINES, NATIONAL COPPER MINING CO., MULLAN, IDAHO

Usually one cleaner will be sufficient to take care of four roughers. The froth formation and pulp density will now be considered.

Froth Formation

The froth is generated as the result of injecting the finely divided air into the bottom of the already emulsified pulp, and it continues to form and to overflow so long as it is furnished with pulp of the proper consistency, properly mixed, and with the right quantity and kind of oil or frothing agent. Measured from the water level within the tank, the froth produced may be from 14 to 16 in. in depth or thickness, and according to the kind of ore, kind and quantity of oil introduced will be more or less voluminous, coarse or fine grained, dry or watery, all of these conditions being adjusted by the regulation of the kind or quantity of oil and the quantity of air injected.

On some ores, rich in sulphides, and where a comparatively low grade concentrate will suffice, the cleaner

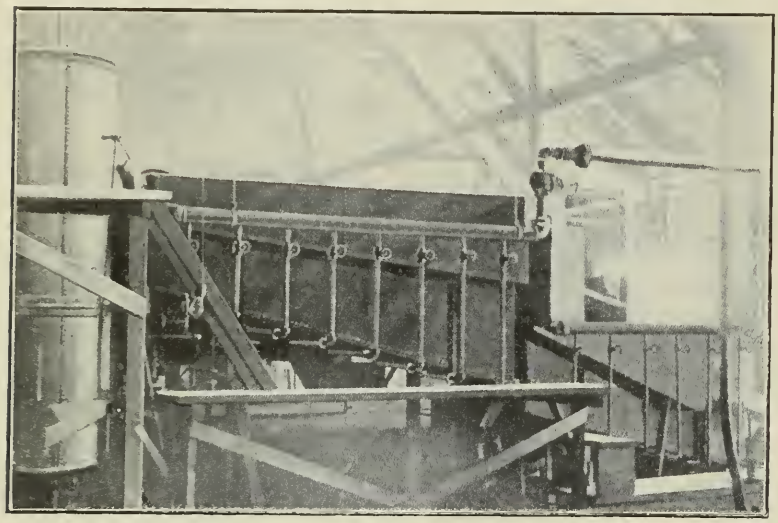


FIG. 3—30-TON EXPERIMENTAL UNIT, CALLOW PNEUMATIC FLOTATION MACHINES, DALY-JUDGE MILL, PARK CITY, UTAH

may not be necessary, but on low grade ores having a high ratio of concentration and where a concentrate of extreme cleanness and of maximum grade is required, a cleaner is desirable.

Pulp Density

The pulp to be treated may be of varying density from $2\frac{1}{2}$ water to 1 ore, up to 6 or 7 to 1. For a mixture of sand and slime the former ratio is preferable, but for a pure slime mixture (minus 200 mesh) a larger proportion of water is allowable. The particular density is not a matter of so much importance as that the supply of pulp shall be uniform as to its density, since each variation in the density of the pulp requires a readjustment of the oil supply, the quantity of oil increasing in proportion to the increased volume of the pulp independent of the solid contents.

Oils

The oils used may be broadly divided into "frothers" and "collectors." The pine oils are good frothers and coal tar and its various subdivisions are good collectors. On some ores, crude pine-tar will in itself combine both the property of frothing and collecting. On others this may have to be enriched by the addition of some one of its more volatile constituents such as refined pine oil, turpentine or wood creosote.

Generally speaking the coal-tar products are poor frothers, and to get a sufficient volume of froth to insure a high recovery it is often necessary to add refined pine oil, creosote, etc. At Inspiration, for instance, the mixture is 85 per cent crude coal-tar, 15 per cent light oil or creosote, 5 per cent pine oil. At Daly-Judge, 40 per cent crude coal-tar, 40 per cent creosote, 20 per cent pine oil. In the Coeur d'Alenes, on zinc ore, straight wood creosote; on the National copper ore plain turpentine will work, but pine oil is better. At Inspiration it required from $1\frac{1}{2}$ to 2 lb. of the mixture per ton of ore; at Daly-Judge 1 to $1\frac{1}{2}$ lb. and at the National 3/10 of a pound of oil is sufficient. The proper kind or kinds of oil and the quantity requisite can only be determined at present by tentative experiment; so far there is no scientific way known.

Character of Froth

The nature of the froth made by the pneumatic process has the distinctive characteristic of being unstable or ephemeral; that is, it quickly dies when removed from the action of the injected air. The bubbles composing the froth being generated under a hydraulic pressure varying from 15 to 37 in., on rising above the water and to the froth level, burst by reason of the lower surrounding atmospheric pressure. On bursting they release the mineral coating them, but this in turn is caught up by those bubbles immediately following behind. The instability or stability of the bubbles will depend upon the oil used and the nature of the ore gangue. Pine oil makes a very brittle froth which dies immediately on arriving at the surface. Creosote and light oil make a very elastic envelope which at times will expand into bubbles 3 or 4 in. in diameter before bursting. The pine oil bubbles will rarely be over $\frac{1}{4}$ or $\frac{1}{2}$ in. in diameter. Castor oil, olive oil, candle makers' oil (oleic acid), palm oil, sperm oil and other oils of a lubricating nature have in general been replaced by oils more or less soluble or miscible in water, such as turpentine, pine oil, eucalyptus oil and all the other coal and wood-tar distillations. The very volatile oils such as naphtha, gasoline, ether and alcohol seem to serve very little purpose except as means for making the pitchy ingredients of coal and wood-tars more soluble or miscible.

With the present knowledge of the subject it is impossible to state by a visual examination or an analysis of the ore, whether or no it can be successfully treated by flotation. Only properly conducted tests can determine this. The General Engineering Company of 159 Pierpoint Street, Salt Lake City, Utah, has equipped its testing plant for conducting the necessary preliminary tests for which an average 100 to 150-lb. sample will generally suffice. Should the preliminary tests show encouraging results, it is advisable to follow them up by the installation of a 20 or 30-ton experimental unit in the plant, or where there is no plant in existence a 5-ton sample can be sent to the General Engineering Company for further and final investigation.

Materials of engineering construction will receive special attention in the proceedings and discussion of the International Engineering Congress to be held in San Francisco next September. The field will be treated under 18 or more topics, covering: Timber resources; preservative methods; brick and clay products in general; life of concrete structures; aggregates for concrete; water proofing; volume changes in concrete; world's supply of iron; life of iron and steel structures; special steels; status of copper and world's supply; alloys; aluminum; testing of metals, of full sized members, and of structures.

Magnetic Separation of Zinc-Iron Sulphide Ores

Some tests recently conducted by the Campbell Magnetic Separating Company of Boston, Mass., in its plant at Cuba City, Wis., on the separation of the sulphides of iron and zinc are described in a pamphlet issued by the above company. The process consists in roasting the ore in a special kiln for from three to five minutes, then feeding it over a table in a thin layer on which it is agitated and exposed to the magnet. The

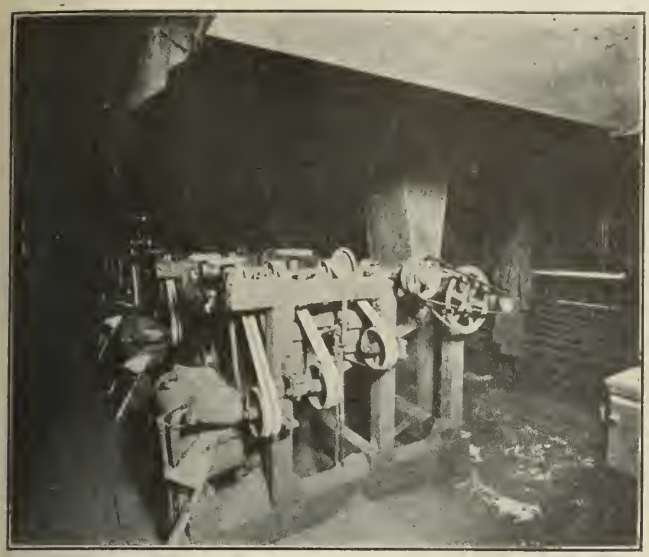


FIG. 1—VIEW OF EIGHT CAMPBELL MAGNETIC SEPARATORS INSTALLED IN THE COMPANY'S PLANT IN CUBA CITY, WIS.

iron is removed and the zinc flows on over the end of the table.

The following figures give the results of a seven-day test made upon the plant at Cuba City by Mr. Charles L. Constant of New York City.

Assay of raw ore:

Moisture	3.75 per cent
Zinc	16.50 per cent
Iron	33.00 per cent
Sulphur	42.49 per cent
Lime	1.95 per cent

Assay after roasting:

Zinc	19.20 per cent
Iron	37.80 per cent
Sulphur	35.30 per cent
Lime	1.12 per cent

Zinc concentrate after separating:

Zinc	60.75 per cent
Iron	2.05 per cent
Sulphur	29.95 per cent
Lime	2.00 per cent

Iron concentrate after separating:

Zinc	1.25 per cent
Iron	53.30 per cent
Sulphur	37.35 per cent
Lime	1.05 per cent

Further information is taken from the records of the Linden Zinc Co., Linden, Wis., who are using the Campbell system. Its average recovery of metallic zinc for 1914 was 95.4 per cent, the zinc in the iron varying between 0.60 per cent to 4 per cent and the average percentage of sulphur in the iron being about 35 per cent. Low operating costs and the small amount of labor required are other advantages claimed for this process and also its adaptability to the lowest-grade zinc ores, and table middlings and treatment of chalcopyrite.

At St. Louis University the gold medal for the best essay on the "nitrogen problem" has been awarded to Mr. Sylvester Flottemesh.

Titanium

"Geology of the Titanium and Apatite Deposits of Virginia," by THOMAS LEONARD WATSON and STEPHEN TABER, is the title of Bulletin 3A of the Virginia Geological Survey. This beautifully illustrated description of exhaustive field work and laboratory investigation on the Virginia deposits is without doubt the most complete work yet published on titanium ores. It also includes a large amount of general information on titanium which should make the volume one of great value to those interested in this subject. The commercial value of some of the Virginia deposits makes the discussion not only of scientific but also of economic importance.

The first chapter of the bulletin discusses the history, chemistry and ores of titanium with their distribution and occurrence, including a complete table of titanium minerals. The second chapter describes the occurrence and geographic distribution of rutile with descriptions of the areas in which it is found. This includes foreign countries, the principal ones being Canada, Norway and South Australia. Photomicrographs of specimens from Australia and Norway show the nature of these rutile-bearing rocks.

Chapter III begins the main portion of the volume, giving the results of the field and laboratory work in Virginia on the ore deposits of the Amherst-Nelson counties region. Topographical maps, photographs and photomicrographs interspersed throughout the text explain the rock formations, and analyses are given to show the chemical composition. "The region is shown to be a comagmatic area of unusual scientific interest, many of the rock-types of which are new and described in detail for the first time." This is the most important district commercially and its description takes up about two-thirds of the volume. Included in this chapter are also individual descriptions of mining properties in this district, the principal mine being that of the American Rutile Company. This is followed by a description of the general petrology of this region.

The fourth chapter discusses the ilmenite-apatite deposits in Roanoke County. These are also commercially important, as are those which were recently discovered in Goochland and Hanover counties and described in Chapter V. Chapters VI and VII describe the occurrence of rutile in Charlotte and Buckingham counties, in which the deposits are of scientific interest only. In the last two chapters economic considerations are discussed, mining methods are suggested and possible by-products mentioned. It is stated that the future of rutile mining in Virginia looks very encouraging as there is practically an unlimited supply of very pure rutile in the Amherst-Nelson counties area, and with the prospecting in the other districts and the development of new uses for titanium an increasing demand is expected which ought to stimulate production.

The utilization of heat from slag, under the Vautin and Johnson patents, is described in a booklet issued by Slag Power, Ltd., Salisbury House, London, England. The method of operation is illustrated and described, and the results of experiments are given showing the available heat that may be obtained from copper and iron slags. Tests indicate that 1000 kilos of copper slag contain from 318 to 350 calories of available heat, and upwards of 500 kilos of water have been evaporated per 1000 kilos of slag. In the case of iron slag the available heat per 1000 kilos is 550 calories, and upwards of 740 kilos of water have been evaporated per 1000 kilos of slag.

National Exposition of Chemical Industries

The opening of America's first National Exposition of Chemical Industries on Monday, Sept. 20, is looked forward to with great interest, as it is an event which cannot fail to be far reaching in its results. It will bring into closer contact than ever before the manufacturers, financiers, dealers and consumers. Elaborate exhibits are arranged, many of them working units, giving visitors the opportunity of seeing the processes in actual work. The character of the exhibitors assures the success of the undertaking.

An invitation has been extended by the advisory committee to President Wilson to be present and participate in the opening of the exposition.

Among the institutions which have co-operated to make this exposition a success are the American Chemical Society, American Electrochemical Society, American Institute of Mining Engineers, American Institute of Electrical Engineers, American Pulp and Paper Associations' Technical Section, and the Bureau of Commercial Economics. Following is an incomplete program which will have numerous other papers and addresses added:

Monday, Sept. 20

Opening day.

Tuesday, Sept. 21

D. P. Pierce (Barber Asphalt Company), "Work with the Ultra Microscope."

Howard H. Gross (president Tariff Commission League) will lead a discussion on the tariff question in which other members of the league will participate.

R. S. Frinck (president Frinck Pyrometer Company), "The Relation of Chemistry and Mechanical Manipulation to the Evolution of the Glass Industry."

Harrington Emerson (the Emerson Company), "Efficiency."

Meeting of the New York Section of the American Electrochemical Society

Wednesday, Sept. 22

Thomas H. Norton (U. S. Department of Commerce), "Foreign Markets for American Chemicals."

F. W. Keough (president National Association of Manufacturers), "Accident Prevention in the Chemical Industries."

Welding Ring (president American Exporters' Association), "Transportation and Shipping Facilities with Foreign Countries."

I. F. Stone (president National Aniline & Chemical Company), "The Aniline Dye Situation."

J. L. Lightner (Hershey Chocolate Company), "The Manufacture of Chocolate."

Thursday, Sept. 23

J. L. Taylor (U. S. Bureau of Mines), "Explosives."

H. A. Huston (German Kali. Co.), "Potash."

Linn Bradley (the Research Corporation), "Solution of Smoke, Dust and Fume Nuisances by Electrical Precipitation."

Percy Wilson (secretary Association of American Portland Cement Manufacturers), "The History of Cement."

Meeting of the American Paper and Pulp Association (Technical Section)

Friday, Sept. 24

S. P. Sadtler (S. P. Sadtler & Sons), "American Contributions to Industrial Chemistry."

W. D. Coolidge (General Electric Company), "The X-Ray."

Joint Meeting of the New York Section American Chemical Society and the American Institute of Chemical Engineers

Saturday, Sept. 25

John Barrett (director Pan-American Union), "South American Opportunities."

Geo. Frank Lord (DuPont DeNemours Powder Company), "Farming with Dynamite."

G. B. Heckel (New Jersey Zinc Company), "Zinc."

A motion-picture program has been arranged for by the Bureau of Commercial Economics at Washington. This will include various manufacturing processes, mining industries, uses of electricity, and general factory management, and should prove an exceedingly interesting and instructive feature. Many of the exhibitors will also have speakers in the auditorium, who will lecture and display by motion and slide pictures the work of their respective companies.

This lecture and picture program will be announced from day to day on the exposition bulletin boards.

Under the auspices of the Bureau of Foreign and Domestic Commerce, some eight bureaus in the Departments of Commerce, Interior and Agriculture are now arranging noteworthy and instructive exhibits, each of which will be typical and demonstrative of the work of that bureau.

Among the exhibitors at this exposition are the following:

Abbé Engineering Co.
American Hard Rubber Co.
American Chemical Society.
American Bitumastic Enamels Co.
Automatic Weighing Machine Co.
J. T. Baker Chemical Co.
Brown Instrument Co.
W. Beckers Aniline & Chemical Works, Inc.
Bethlehem Foundry & Machine Co.
Buffalo Foundry & Machine Co.
Boonton Rubber Mfg. Co.
Christian Becker.
Condensite Co. of America.
Chemical Process Co.
Chadwick Boston Lead Co.
Department of Commerce, Washington, D. C.
J. P. Devine Co.
Driver-Harris Wire Co.
DuPont DeNemours Powder Co.
Duriron Castings Co.
Dorr-Cyanide Machine Co.
Detroit Range Boiler Co.
Thos. A. Edison.
Elyria Enameled Products Co.
Eimer & Amend.
Fairview Fluorspar & Lead Co.
General Bakelite Co.
General Chemical Co.
Gerdes & Co.
Glens Falls Machine Co.
Emil Greiner & Co.
Hanovia Chemical & Mfg. Co.
Heller & Merz.
Huyck & Sons, F. C.
Huff Electrostatic Co.
International Instrument Co.
Kieselguhr Co. of Amer.
Koven & Bro., L. O.
Lead Lined Iron Pipe Co.
Lenz & Nauman (Scientific Specialties Co.).
Lungwitz, Emil
Metallurgical & Chemical Engineering.
Macbeth-Evans Glass Co.
Moore Filter Co.
Monsanto Chemical Works.
J. L. Mott Iron Works.
National Aniline & Chem. Co.
Norton Co.
Pfaudler Co.
Raritan Copper Works.
Schaefer & Budenberg.
Schaum & Uhlinger, Inc.
Scott & Co., Ernest.
Standard Aniline Products, Inc.
Sweetland Filter Press Co.
Swenson Evaporator Co.
Thwing Instrument Co.
Tolhurst Machine Co.
Troegerlith Tile Co.
United Lead Co.
Valley Iron Works
Wilson-Maeulen Co.
Zaremba Evaporator Co.

Supply of Manganese Ore and Ferro-manganese Statistics

From a statement issued by Mr. C. B. Morgan, secretary of the Noble Electric Steel Company of San Francisco, we take the following interesting statistics on manganese ore and ferro-manganese:

MANGANESE ORE

	1913 Tons	1914 Tons	1915 Tons
Imports into the United States	345,090	283,294	.....
Average per month	28,757	23,608	.....
Imports first half 1915	.....	.....	52,007
Average per month	.....	.....	8,700
Imports into England	601,177	479,435	.....
Five months ending May, 1915	.....	.....	107,297
Imports, May, 1915			5,278
Or at a yearly rate of			63,000

FERROMANGANESE

Average imports in the United States, embracing 1910-1914	100,793 tons
Production from imported ore	99,363 tons
Total available yearly supply	200,156 tons
Average imports per month	8,399 tons
Production	8,280 tons
Total available monthly supply	16,679 tons
Imports first half 1915	20,542 tons
Possible production	15,500 tons
Total available supply	36,042 tons
Total available monthly supply	6,000 tons

It will be observed that the first half of 1915 the supply has been 10,000 tons per month less than the average of the preceding five years, or a deficit of 60,000 tons.

Before the war 90 per cent of the importations of ferromanganese came from England, which is now the only foreign source of supply, and as the imports of ore into England are on a diminishing scale, it becomes an interesting question, to what extent England can fill the growing void in the United States. Upon the scale of imports of manganese ore into the United States shown in the first half of this year only a partial relief can be expected from domestic production.

Personal

Mr C. W. **Badgley**, of the El Paso Smelting Works, has been spending his vacation in Denver, Col.

Mr. **Walter E. Burlingame** announces that the business of E. E. Burlingame & Co., assayers and chemists, will hereafter be conducted under his name at the old location, 1736 Lawrence Street, Denver, Col.

Messrs. **F. G. Cottrell** and **Dorsey A. Lyon**, of the Bureau of Mines, have been in the Coeur d'Alene district, Idaho, preparing for some technical studies in local ore treatment under a co-operative arrangement between the bureau and local operators.

Mr. **Justin H.Haynes** has returned to Denver after four months' professional work near Searchlight, Nevada, and will be engaged in metallurgical work in Colorado.

Dr. **F. W. McNair**, president of the Michigan College of Mines, recently made a trip through Ontario, visiting Cobalt, Porcupine and Sudbury, where he was entertained by alumni of the college.

Mr. **H. C. Parmelee**, Western editor of METALLURGICAL AND CHEMICAL ENGINEERING, has been appointed by the Governor of Colorado as a trustee of the Colorado School of Mines. The other appointees are Mr. **Orvil R. Whitaker** of Denver and Mr. **H. M. Rubey** of Golden.

Mr. **W. H. Staver** is in charge of mining and milling operations on the Suffolk property, Ophir, Col.

Mr. **H. L. Sulman** has been elected president of the Mining & Metallurgical Club, London.

Obituary

In memory of **Albert Plaut**, the late president of Lehn & Fink, and treasurer of The Chemists' Club of New York City, the Board of Trustees of The Chemists' Club has adopted the following minute: The death of our treasurer, Albert Plaut, inflicts on The Chemists' Club and its members a very great loss. His unflinching interest in the club's affairs, his generous helpfulness on every occasion that offered itself, his keen interest in the work of chemists and his encouraging appreciation of these efforts, his sturdy maintenance of what he regarded as right, together with his gracious good fellowship, all endeared him to the large number of us who knew him. And while we record our poignant grief at his passing, we acknowledge both appreciation and pleasure in that ours was the privilege to be associated with one who ordered his life to such good ends and whose friendship was indeed a benediction to those who shared it.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Anodes

546,483, September 17, 1895, Henry L. Bridgman, of Blue Island, Illinois.

Relates to anodes for electrolysis and consists of a frame which may be of insulating material, or of lead, copper, or other conductor that is not attacked by the electrolyte. The frame supports a plurality of V-shaped pockets separated at the bottom, and placed one above the other, spaced apart a distance approximately equal to the depth of the pocket. Above the pockets is a hopper, and below a movable board serving as a stop for the anode material supplied to the hopper. A pipe is provided to supply electrolyte to the anode material, to wash out any sludge, also a stirring rod to prevent the anode material from becoming too compact. The kind of anode material used is not described.

553,464, January 21, 1896, Eugene Hermite, of London, England, assignor of two-thirds to Edward James Paterson and Charles Friend Cooper, of same place.

Relates to anodes, and describes securing a network of platinum wires to a glass plate. The plate is drilled with a plurality of holes, all over the plate, and platinum wire is either threaded through the holes, so as to produce as complete a net-work as possible, or insulating studs are inserted in the holes, and the platinum wire supported by the studs. The net-work of wire may be on one side or both sides of the plate.

568,229, September 22, 1896, Henry Blackman, of New York, N. Y.

Relates to anodes for electrolysis of alkali chlorids, preferably for making bleaching liquor, and contains a reference to a copending application which became patent 568,231. The anode consists of an oxid of iron, or a mixture of oxids, bonded with a suitable binding or fluxing material. The material preferred is known as "black slag," a residue from pig-iron furnaces; it is fusible, and may be cast into any desired shape. The

black slag may, if desired, be mixed with magnetite, or other oxids of iron, or pulverized carbon.

568,230, September 22, 1896, Henry Blackman, of New York, N. Y.

Relates to anodes for electrolysis of alkali chlorids and describes making the anode from the mineral "ilmenite" or titanium-iron-oxid. The material is either sawed into shape, as is a block of granite, or may be melted with the aid of a small quantity of fluxing material and cast.

568,231, September 22, 1896, Henry Blackman, of New York, N. Y.

Relates to anodes for electrolysis of alkali chlorids, and describes magnetite and ilmenite, which may be shaped by sawing, melting and casting, or pulverizing and mixing with a binding material such as tar and molasses, pressing into the desired shape and baking.

572,472, December 1, 1896, Hamilton Young Castner, of London, England.

Relates to anodes for electrolytic purposes, and describes heating a piece of gas-retort carbon, eighteen inches long by one inch square cross section to an immeasurable temperature by passing an electric current of about five hundred amperes for a few minutes, the carbon rod being covered by powdered charcoal to protect it from oxidation. After cooling the rod possessed decreased density and increased conductivity, and was less susceptible to chemical action than before treatment.

578,070, March 2, 1897, Albert E. Woolf, of New York, N. Y., assignor to Rosamond Woolf, of same place.

Relates to anodes for electrolysis and describes a sheet of platinum or similar difficultly corrodible metal or alloy, about one one-thousandth of an inch thick, comparatively narrow, and having a length several times its width, secured at one of its longer edges and two short edges to a base metal such as copper, iron, etc.; the base metal serving as the conductor and insulated with glass, enamel, etc. The electrode thus insulated may be safely immersed in an electrolyte and used as an anode at which corrosive gases are liberated.

621,121, March 14, 1899, John T. Morrow, of Great Falls, Montana.

Relates to a supporting means for copper and similar anodes, used in copper-refining. The supporting means consists of folded straps of pure rolled sheet copper having their ends cast into the impure anode. The straps serve as supports and conductors and effect an economy in the amount of copper to be remelted when the anode is consumed.

627,573, June 27, 1899, Charles Cunningham Connor, of Belfast, Ireland.

Relates to anodes for electrolysis and describes uniting pieces of gas-carbon, graphite, coke, etc., together by lead. The carbon blocks of carbon may be drilled, supported in a frame, separated by asbestos washers and lead poured into the drilled holes and washers. Or the carbon blocks may be thrust part way into sand, and a layer of molten lead poured on the sand securing the carbons in such a position that they project equally on each side of the lead layer, the latter serving as the conductor. Or the carbons may be drilled and bolted on the sides of a lead plate having projecting lugs. In each case the lead plate, etc., is insulated with enamel, pitch, etc.

633,056, September 12, 1899, Arthur L. Walker, of Perth Amboy, New Jersey.

Relates to a supporting and connecting means for copper anodes and consists in casting the crude anodes with holes or perforations in the "ears" or lugs, in which supporting bolts or "eyes" may be secured, thereby effecting an economy in the amount of undissolved anode to be recast.

639,811, December 26, 1899, Harry L. Haas, of New York, N. Y., assignor to the Zucker & Levett & Loeb Company, of same place.

Relates to a supporting hook for anodes, which is integral with the anode, and is provided with broad flat square-jointed faces or surfaces by which the anode is suspended, and by which electrical contact is made.

658,891, October 2, 1900, Henry Carmichael, of Malden, Massachusetts, assignor to S. D. Warren & Co., of Boston, Massachusetts.

Relates to an anode consisting of a net-work of platinum wire the wire supported upon and secured to projecting pins of platinum, which in turn pass through and are sealed in the ends of glass tubes, the tubes passing through the cover of the electrolytic cell. Connection is made to the inner ends of the platinum pins by copper or other wire, the tube then being filled with pitch, etc. Instead of the net-work of platinum wire, each glass tube may support a long piece of platinum wire folded into a plurality of loops. Instead of glass tubes, vitrified porcelain may be used, which is said to be more durable in contact with chlorin than the glass.

667,421, February 5, 1901, Henry Blackman, of New York, N. Y.

Relates to means for making electrical connection with anodes or other electrodes, and consists in boring a hole in the top of the electrode down into its mass, as large in diameter as its thickness will permit. In the hole is inserted preferably a zinc rod having a spiral roll of hard rolled sheet zinc secured to it and wound tightly upon it. The rod and spiral roll are forced down into the hole, the spiral making good contact with the walls of the hole. Upon the rod and into the hole is forced a hard rubber tube, carrying upon its lower end a soft rubber ring, the soft rubber making a tight joint with the walls of the hole, the lower part of the hard rubber being beveled to make a tight joint with the upper edges of the hole. The hard rubber tube projects above the level of the electrolyte and is provided with a screw-threaded ring or cap which compresses a packing tightly against it and the conductor to prevent access of liquids to the interior of the tube.

667,498, February 5, 1901, William Thomas Chapman, of Manchester, England, assignor to the American Alkali Company, of Philadelphia, Pennsylvania.

Relates to means for vertically adjusting the height of electrodes in a cell, to allow for wear, breakage, etc. The upper end of the electrode has attached to it a threaded conductor rod by which it is supported from a threaded sleeve, which permits raising or lowering as may be desired.

673,453, May 7, 1901, Isaiah L. Roberts, of Brooklyn, New York, assignor to the Roberts Chemical Company, of New Jersey.

Relates to a connector for granulated carbon electrodes, such as are used in porous cups. The connector consists of a metallic plate embedded in a conducting cement, made of resin, asphaltum, and a conducting material, preferably carbon; between the cement and the granulated carbon electrode is a layer of powdered carbon such as coked anthracite coal, to improve the electrical contact. For large electrodes several contacts may be placed at different positions. The entire top is then covered with asphalt or similar seal.

689,877, December 31, 1901, Luke Hargreaves and William Stubbs, of Farnworth in Widnes, England.

Relates to anodes and provides means for protecting the metallic part thereof from corrosion by the electro-

lyte. Where blocks of carbon are secured to a vertical metallic conductor, the latter is encased in a tube of protecting material, the tube being filled with a suitable oil, such as a resin oil containing resin dissolved in it, the oil completely covering the metallic parts, and penetrating by capillarity the pores of the carbon. With electrodes suspended from a horizontal metallic conductor, they pass through a shallow tray containing the oil, the tray resting upon the cell.

715,684, December 9, 1902, Frank McDonald, of Johnsonburg, Pennsylvania.

Relates to anodes and consists of a plurality of strips of thin ribbon platinum-foil, which may be two inches wide in some cases and of suitable length, sealed into the end of a glass tube, containing mercury, into the upper end of which projects a conductor. The tube may be closed by a plug of cement forming an air-tight and liquid-tight joint.

(Complete prior to 1903.)

Notes

The Lack of Coke and Iron in Italy.—According to the Chamber of Commerce of the U. S. (Riggs Building, Washington, D. C.) the war has stopped in Italy entirely the arrival of foundry coke and low-grade pig iron from Germany, and the local Italian producers (Solvay Process Works at Vado and Savona near Genoa) are closed because they have no coal, and until the war is over very little coal and coke will come from England from which country Italy has been importing about 70,000 tons of coke per year. The imports from Germany, Austria and Belgium amounted to 220,000 tons of coke per year. The metallurgical or hard foundry coke which has come from Westphalia in the past was delivered in Milan at from $11 to $12 a ton, and at the present those who have any coke in stock are getting anywhere from $20 upward a ton. The unloading and putting on cars at Genoa and Savona is about 50 cents a ton, and the freight from these ports to Milan is just under $2 a ton. The port of Savona has special facilities for unloading coal and coke. There is a big demand for iron in Italy that compares in analysis with English hematite. American pig iron for malleable use, as well as the more ordinary quality, in the general foundry business, is also wanted. If the makers of pig iron care to investigate what appears to be an opening in Italy, the American Chamber of Commerce in Milan will be pleased to have them send over their analysis together with prices at the seaboard in America, as well as in Genoa. The hematite which sold before the war at about $21 delivered in Milan is not to be had now at less than $45 to $50, as the only iron ore available is Spanish hematite, of which the quantity is limited. The landing charges, freight and duty from steamer to delivery in Turin or Milan are about $4.50, of which $2 is freight, $2 duty and the rest handling and unloading.

The standard riffles on a Wilfley table vary progressively in length from 4 ft. 6 in. to 13 ft. 10 in. In depth they are tapered from ¼ in. to 1/16 in. in the shorter rifles, and from ⅜ in. to 1/16 in. in the long ones.

The price of tungsten concentrates in the Boulder county field, Colorado, has advanced to $10 per unit for 60 per cent WO_3, or $600 per ton. According to a consular report, the price for ferrotungsten in England has advanced to $1.34 per pound of tungsten contained in the alloy, and tungsten powder to $1.46 per pound.

The Petroleum Industry of California is the subject of a 600-page book, with a separate folio of maps, issued by the California State Mining Bureau, Ferry Building, San Francisco, Cal. The price is $2.

The study of sanitary conditions in and about mining and metallurgical plants has been undertaken by the Bureau of Mines. Some results of an investigation by Joseph H. White are embodied in *Bulletin* 87, entitled "Houses for Mining Towns." The bulletin contains illustrations and designs, showing good and bad conditions, and outlines the work done by large companies in laying out and maintaining mining settlements.

Book Reviews

Chemical Theory and Calculations. By F. J. Wilson and I. M. Heilbron. Price $1.00 net. New York City: D. Van Nostrand Company.

A first-class little book for beginners, if used under a good teacher. The explanations of fundamental chemical quantitative relations (such as of equivalent weights) are clear and convincing. The only drawback is that here and there a word is used loosely, or a necessary qualifying phrase omitted, which would need the attention of a sharp-eyed teacher to straighten out and thus prevent the student getting a fragmentary or faulty idea. The problem method is the only method to make absolutely certain that a student has mastered the fundamentals; for, if a student can work out a complicated problem correctly one may be sure that he is properly master of the principles involved.

Details of Cyanide Practice. By Herbert A. Megraw. Octavo (15 x 22 cm.), 215 pages, numerous flow sheets, drawings and illustrations; price $2 (8/4). New York and London: McGraw-Hill Book Company, Inc.

The work describes cyanide practice at fifteen important mills in North America, the facts being gathered from a tour which was intended to include Mexico, but this was prevented by the revolution in progress there. The chapters have already appeared as a series of descriptive articles in the *Engineering and Mining Journal*. The work presents the author's observations and personal opinions, and criticisms intended to promote discussion respecting details involving diverging practice.

Cyanide Practice, 1910 to 1913. Edited by M. W. von Bernewitz. Octavo (15 x 23 cm.), 732 pages, 133 illustrations. Price, $3. San Francisco: Mining and Scientific Press.

This a reprint of 205 articles which appeared in the *Mining and Scientific Press* from July, 1910 to January, 1913. It is a continuation of two similar compilations printed in 1907 and 1910. A great improvement over its predecessors is the classification of the articles under fifteen headings, conforming to the arrangement of the ordinary treatise on the cyanide process, instead of merely arranging them chronologically.

There is an immense amount of up-to-date information on the cyanide process in this book, written from many different standpoints and, therefore, of greater suggestiveness and value than if written by a single author. Incidentally, when one reflects that this mass of useful information was furnished by one single journal, from week to week, in timely installments, and that this is only one of several subjects covered by that journal, one obtains a vivid idea of the immense value given, at relatively small cost, by the columns of the active technical journals. This book is valuable in and of itself, but it proves the still greater value of the

periodical scientific press to the wide-awake technologist.

Methods in Metallurgical Analysis. By **Charles H. White.** Duodecimo (12 x 18½ cm.), 356 pages, 106 illustrations; price $2.50. New York: D. Van Nostrand Company.

The author is assistant professor of mining and metallurgy in Harvard University and the Massachusetts Institute of Technology. The book is intended for the use of students who have had adequate preparation in qualitative analysis and gives them the methods which have been most generally adopted in American metallurgical laboratories. The details are clearly stated in a manner indicating the author's long practice in teaching; the style is good, the methods well chosen, the printer's work first class. It is undoubtedly a very welcome book for the use of metallurgical students.

Metallurgy. By **Henry Wysor.** Second edition, revised and enlarged. 392 pages, 104 illus. Price, $3. Easton, Pa.: The Chemical Publishing Company.

A condensed treatise for the use of college students and the general reader. The bulk of it is good, though some parts less so; it is all necessarily brief. There is a very large amount of information in the book, of a kind adapted to give the reader a general idea of every phase of the subject. It is essentially a textbook, adapted for use as such by assigning lessons in it from cover to cover. For those who are so placed that they must teach metallurgy merely as a branch of industrial chemistry, this is probably as good a textbook as could be selected; but some omissions would need to be supplied and some errors corrected: *e.g.*, omission of petroleum among the fuels, explanation of *how* mercury ore is decomposed by heat, or the kind of electrodes in aluminium reduction pot. It is a book which might be satisfactorily used in giving an elementary course.

Steel Working and Tool Dressing. By **Warren S. Casterlin.** 12 mo., 207 pages. Price, $2. New York: M. T. Richardson Company.

The sub-title reads "A Manual of Practical Informationo for Blacksmiths and All Other Workers in Steel and Iron." The author is a practical blacksmith who has spent fifty-seven years at the anvil. He says in the preface: "I have worked in more different shops, done more traveling, and spent more time and money to perfect myself in the art of steel working than any other man on the continent." Again he says: "I shall never revise this book again. I have tried to do my duty. I have been cautious at every stroke of the pen."

It is difficult to criticise such an honest bit of writing. It is written in absolute sincerity, and it contains the quintessence of the experience and beliefs of the old, old school. Peace be to their ashes! No one can read it without learning some items of practical information; yet it is the duty of the reviewer to caution readers against the limitations of the author and the many errors in the book. The uninstructed would learn from it much that is questionable and some things that are wrong; they had better, therefore, leave it alone until they know more about steel from more reliable sources. Those initiated in steel will find it an interesting human document, and may find in it some crumbs of useful information.

Heat-Treatment of Steel. Collected from articles in *Machinery*. Octavo, 278 pages, illustrated; price $2.50. New York: The Industrial Press. London: The Machinery Publishing Co., Ltd.

This book is mainly compiled from articles published in *Machinery*, with amplifications and additions. It contains a large amount of information and some misinformation, thrown together in a miscellaneous receipt-book sort of way. At places it is quite good, but at others it is pretty poor. A reader well acquainted with the subject might glean some useful information by reading it through critically; one unacquainted with the subject will run the risk of learning it in a disjointed, unsystematic manner which will give him but little real mastery over it. It may be possible that mechanics need to have an art presented to them in this sketchy, jumbled sort of way in order to read it understandingly, but we doubt it.

The Sampling and Assay of the Precious Metals: Comprising Gold, Silver, Platinum, and the Platinum Group Metals in Ores, Bullion, and Products. By **Ernest A. Smith.** Octavo (15 by 22 cm), xv + 460 pages, 166 illustrations; price, $4.50 net.

The author is connected with the Sheffield Assay Office, but was formerly teaching the subject at the Royal School of Mines, London; he dedicated the work to his father, Richard Smith, one of the original staff of the Royal School of Mines, on its formation in 1851.

The author's aim has been to make the book exhaustive and comprehensive. Particular attention is given to sampling. We would describe the treatment as being less scientific than Fulton's "Manual of Fire Assaying," and therefore less instructive to the student. A curious misnomer exists in the title: assay is *"for"* the precious metals, not *"of"* them.

Blowpipe assaying for gold and silver is acknowledged to be useful, particularly to the prospector, and therefore deserved a chapter instead of three-fourths of a page. The miscroscopic measurement of small assay buttons from small amounts of ore or from very lean ores, is not mentioned; also, methods particularly adapted to assaying country rock or sea-water are not given, yet should be considered in a comprehensive treatise.

It is a fine book, but could be improved in a few respects.

Gemeinfassliche Darstellung des Eisenhüttenwesens. Compiled and published by the Verein deutscher Eisenhüttenleute. Ninth edition, octavo. xii + 438 pages, 68 illustrations, many diagrams; price, bound in cloth, 5 marks (retail in New York $1.65). Düsseldorf: Verlag Stahleisen.

A well-written, beautifully printed and illustrated exposition of the present methods of manufacturing iron and steel. The space given to each topic is necessarily brief, but it is utilized most skillfully. To those reading German easily it gives a very readable and instructive picture of the iron industry. Over one-third of the book is devoted to statistics of the iron industry in all parts of the world and nearly one-fifth to an exhaustive list of all the firms making and working upon iron and steel in Germany.

Einführung in die Metallographie und Wärme Behandlung. Von H. Hanemann. 16 x 24 cm., 128 pages, 25 diagrams in the text, 110 photomicrographs on plate paper. Price 10 marks (retail price in New York $3.35). Berlin: Gebrüder Borntraeger.

The author is director of the metallograph division of the iron and steel laboratory at the Technical High School in Berlin. This book embodies twelve lectures given by him to metallurgical, chemical and mechanical engineers in a summer school course. It is, therefore, not a comprehensive text-book, but merely a clear-cut statement of the best of present methods and results in the microscopic study of metals and their improvement by heat treatment. It is clearly written, and the photographs are excellent and most instructive.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, SEPTEMBER 15, 1915 No. 10

Published Semi-monthly on the First and Fifteenth of Each Month by the

McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.

A. E. Clifford, Secretary. John T. DeMott, Treasurer

239 West 39th St., New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Col.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for September 15, 1915

EDITORIAL:

California and the International Engineering Congress.. 579
A Bit of Economic Mineralogy..... 581
The Iron Trades' Divergences Under War Demand..... 581

READERS' VIEWS AND COMMENTS:

The Potash Situation. By J. W. Beckman..... 582
Repairing Furnace Linings with Compressed-Air Gun and Torch. By Alfred Schwarz..... 582
Metallurgical and Chemical Engineering in Great Britain.... 583
Notes..... 585
Seattle Meeting of the American Chemical Society..... 587
The Industrial Resources and Opportunities of the Northwest. By H. K. Benson..... 589
The Improvement of High-Boiling Petroleum Oils, and the Manufacture of Gasoline, as a By-Product Therefrom, by the Action of Aluminium Chloride. By A. M. McAfee.... 592
The New Mill of the Daly West Mining Company, Park City, Utah. By L. O. Howard..... 597
San Francisco Meeting of American Institute of Chemical Engineers..... 603
Resources and Possibilities of Chemical Industry in the Southwest. By E. Baruch..... 604
The Fleming Dust Collecting System. By W. C. Hanna..... 609
Manufacture of Cream Tartar. By Otto Best..... 613
Gold Milling in California—A Comparison. By Leroy A. Palmer 617
Efficiency of the Blast Furnace Operation. By Birger F. Burman..... 624
Technical Society Meetings and Lectures at the National Exposition of Chemical Industries..... 629
The Open Hearth Versus the Electric Furnace in the Manufacture of Commercial Steels. By Sidney Cornell..... 630
Production of Zinc Oxide from Low-Grade Carbonate Ore at Leadville..... 631
Chemical Principles of the Blast Furnace. By J. E. Johnson, Jr..... 634
Synopsis of Recent Chemical and Metallurgical Literature..... 638
Recent Chemical and Metallurgical Patents..... 641
A New Multiple-Type Recording Instrument for Pyrometers. 643
Determination of Critical Points in Iron, Steel and Alloys... 643
Titan Bronze..... 645
Hydraulic Hardness Testing Machine..... 646
Personal..... 646
Book Review..... 646

California and the International Engineering Congress

Next week, from Sept. 20 to 25, the International Engineering Congress, to which sunkissed California has invited the engineers of the world, will meet in San Francisco. That it will be a great success is assured by the simple fact that San Francisco is the hostess and the national societies of civil, electrical, mechanical, and mining engineers stand sponsor. But it is a melancholy reflection to think that this is the only survivor of so many congresses planned.

The year 1915 was intended to be one of promotion of international good will and friendship by international congresses. It was not so to be. There has been no International Congress of Applied Chemistry in St. Petersburg or Petrograd, no International Congress of Mining, Metallurgy, Engineering and Economic Geology in London. Even the International Electrical Congress which had been planned for San Francisco was called off, and this is characteristic. The Electrical Congress was managed in the East and was called off; the Engineering Congress was managed from San Francisco, and its managers with true Californian spirit stuck to their purpose and carried it through and will achieve the success which their courage deserves.

That in number of members and in international character the International Engineering Congress will seriously suffer from the European war goes without saying. That it can nevertheless be made a real success San Francisco will prove. It is true that the conditions resulting from the European war even in neutral countries have greatly reduced the anticipated enrollment of members, but they have not resulted in a proportionate reduction in either the quality or the quantity of the papers offered for publication in the Transactions. And the Transactions are, after all, the final test of the success of the Congress. But that the Congress and its Transactions should be of the greatest possible benefit to the engineering professions, it is essential that it should enroll the greatest possible number of members.

It is not yet too late to join the Congress. The address of the International Engineering Congress is Foxcroft Building, San Francisco, and the membership fee is five dollars, which entitles the member to full participation in the Congress, a volume reporting the general proceedings, and any single volume of the Transactions which the member may select out of the set of ten volumes. These ten volumes relate to (1) Panama Canal; (2) Waterways and Irrigation; (3) Municipal Engineering; (4) Railways and Railway En-

gineering; (5) Materials of Engineering Construction; (6) Mechanical Engineering; (7) Electrical and Mechanical Engineering; (8) Mining and Metallurgy; (9) Naval Architecture and Marine Engineering; (10) Military Engineering. It may finally be mentioned that for the section of metallurgy five symposia have been arranged on iron and steel, copper, gold and silver, zinc, and the utilization of fuels in metallurgy, the editors being Henry M. Howe, E. P. Mathewson, C. W. Merrill, W. R. Ingalls and C. H. Fulton respectively.

So much may be said as to what may be expected in return for the membership fee. But to look at the Congress in this way shows a rather narrow viewpoint, as the idealistic side of the whole undertaking is entirely lost sight of. The Congress was organized to commemorate and celebrate one of the greatest peaceful engineering achievements of recent times—the completion of the Panama Canal. In these frightfully distressing war times, the Engineering Congress will emphasize the triumph of the peaceful work of the engineer. To enroll as a member means to avow the truth of this idea and is but a small tribute to the Californians who have made the congress a reality.

* * *

Yet the courageous manner in which the International Engineering Congress has been organized is but one single expression of the general spirit that moves the whole Californian people. They mind their own business and in that trait alone they are almost without competitors, and that is one reason why Californians can do things that seem impossible elsewhere. And they mind their own business with the full-blooded enthusiasm and never-dying optimism which they inherited from their pioneer ancestors. With the simple faith in the righteousness of their doings, they perform miracles. After the fire of 1906 how could they have built up otherwise in a few years a new and more beautiful San Francisco? How could they have organized otherwise nine years later a World's Fair and make a success of it—a big success, aesthetic, industrial, cultural, and even financial? In these distressing days when the rest of the world is in flames or is shaking, San Francisco stands firm and strong and happy—an inspiration to all who go and see and wonder.

It is a pity that the East in its troubles does not seem able to derive from the West that inspiration which it needs and could get abundantly. At least if it is true that the newspapers give the people what the people want, it is distressing to see in Eastern newspapers nothing but glaring headlines on the European war. Has anyone seen in any New York newspaper a headline on the wonderful success which San Francisco is making, even beyond her own expectations? Must we always look backward toward Europe? Have the people of the East lost the spirit of those pioneers who followed the course of the sun and conquered the West? Can't we learn to look westward and forward toward the Golden Gate and the great empire at the Pacific Coast? Never has been the name of the *Pacific* Coast as true as to-day.

Of course, the one encouraging feature in this situation is obvious; it is that the situation has produced automatically its own remedy. What no argument about the wisdom or decency of Americans seeing America first could have done, has been practically forced upon American travelers by the European war and by the San Francisco and San Diego Expositions. And every Eastern traveler comes back to the East as an enthusiastic voluntary advertising agent of the greatness of the Pacific Coast.

This is a big gain for the East, but it is not the main point for the West. What are as much important for the West as the very large number of average sight-seeing travelers, are the visits of technical and engineering societies. This week, from September 16 to 18, San Francisco has the meetings of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers, and the American Electrochemical Society, previous to the International Engineering Congress next week. Many other societies have met and will meet on the Coast. Of the trip of the American Institute of Chemical Engineers from San Diego to San Francisco and Seattle and of the trip of the American Chemical Society in counter current from Seattle to San Francisco we give quite a full account in this issue. But the interesting point in this connection is this: What has the Pacific Coast for the chemist and what has the chemist for the Pacific Coast?

The mining engineer blazed the trail and the metallurgist followed, and the more the mineral resources of the Pacific Coast will be utilized the more will the chemical training be needed in the metallurgist. This is obvious. The Bully Hill mine is a famous case in point. But outside of metallurgy the chemist's work in California is restricted at present chiefly to oil and gas and to sugar. These are big fields, very big fields. But they seem small compared with the unlimited possibilities not yet touched.

One single example may explain what we mean. A few years ago, a strong-hearted man was shown the immense kieselguhr deposits at Lompoc in Santa Barbara County and the prospects of oil wells were pointed out to him. This did not appeal to him, as any other rich man could have tackled that proposition. What appealed to him was the creation of a new American industry—that of kieselguhr; he had become a true Californian on California soil. The mining problem was simple enough, but the chemical problem of utilization for heat insulation, sugar filtration, oil refining, and we don't know what else, was everything.

There are unnumbered opportunities of this kind for the chemist in the development of the natural resources of the Pacific Coast. Mr. Baruch's paper on the Southwest, like Dr. Benson's paper on the Northwest, will prove suggestive. If the first semimonthly edition of this journal has become almost completely a Pacific Coast issue, let us hope that this is a happy omen on the future interrelation between chemistry and the Pacific Coast.

A Bit of Economic Mineralogy

If you see it in *The Sun*, it's so. We cull the following contribution to economic mineralogy from *The Sun* of Aug. 20:

> One of the effects of the war upon this country has been to develop resources of which we before had no knowledge. This has been shown in the development of dye, potash and certain mineral industries. Now it has been discovered that there are immense deposits of silica in the sand hills of western Kansas, and so great has grown the demand for the substance since the supply from Germany has been cut off that several large plants have been built for treating and marketing it. We have thus been able not only largely to supply our own demand, but to transform what was once considered waste land into productiveness.

The still more important discovery that the coal deposits of Pennsylvania contain large quantities of carbon has rendered that state, at least, independent of imported fuels; and since the scientific application of the oxometer has demonstrated the presence of not inconsiderable quantities of oxygen in the atmosphere of the western hemisphere it is anticipated that before very long respiration may be possible in this country without the use of European oxygen.

The Iron Trade's Divergences Under War Demand

It may be interesting to recount some of the divergences, amounting occasionally to definite dislocations, produced in the iron trade by the demand for war material. As is doubtless quite well recognized, nearly all if not quite all the increased demand for steel, as compared with that of last year, is due to the war. The measure of the demand upon the steel mills is not merely the quantity of war material they are producing, for ordinary domestic buyers, jobbers and manufacturing consumers have been moved to purchase ahead, and to increase their stocks, because the magnitude of the war demand made them fear they would not find themselves with all the material needed unless they were forehanded in their purchases.

An outstanding divergence is the fact that the steel works are producing pig iron at a rate fully 5 per cent in excess of their best previous rate, reached early in 1913, while the merchant furnaces are producing 20 per cent less than at that time. The demand has run to steel, not to iron castings. The iron cannon ball is far in the past.

The demand for steel has run very strongly to open-hearth, but open-hearth steel has become so scarce that many consumers who ordinarily use open-hearth have been induced to take Bessemer. Very likely they are finding it more suited to their purpose than they expected.

For the first time in their history a large use has been found for the rail mills, apart from the rolling of rails. Of course there have been interchangeable mills, rolling billets or rails at will, but few such have been built in recent years. Now a very large tonnage of rounds, over 3 in. in diameter, is being rolled on rail mills, the section being approximately the same weight as that of standard rails. At least half a dozen rail mills are so engaged. The railroads, which have had no occasion since 1907 to worry about securing any delivery desired upon rails, are now seriously concerned over the prospect, and are beginning to buy rails for 1916 delivery.

The rise in the price of spelter, due to the combined influence of England's supplies from Germany and Belgium, equal to 15 or 20 per cent of the world's normal requirements, being shut off, and the large consumption in the manufacture of war material, has almost killed the galvanized sheet industry. About one-eighth the weight of the average gage galvanized sheet is spelter, while over a period of years spelter sold per pound at about three times the price of the uncoated steel sheet. In recent months spelter has been fluctuating between three and five times its former cost. When spelter has advanced the mills were afraid to sell galvanized sheets; when it declined the buyers were afraid to buy and the current production of galvanized sheets is only about one-third normal.

Various price relations in finished steel products have been disturbed. For many years steel plates brought from $1 to $2 a ton more than steel bars, but in the past few months the divergence has been as much in the other direction.

During the first six months of this year finished steel prices rose steadily, by an average not far from $3 a ton, while pig iron fluctuated within narrow limits and showed no general advance. The pig-iron market was largely a function of foundry activity, which was light. Since July 1 there have been sharp advances in pig iron prices. These advances, while harmonizing with the rise in steel prices, have occurred with a much smaller turnover in the pig-iron market than ever before occurred during a similar rise in price, and the advance may perhaps be attributed more to sentiment than to an operation of the law of supply and demand.

The large steel rounds being rolled in tens of thousands of tons a week involve unprecedentedly heavy cropping, the extreme being 35 per cent from the top and 5 per cent from the bottom. Incidentally this cropping is usually required to be done from the ingot and by sawing, which has necessitated some rearrangements in equipment. What to do with the crops is furnishing a more important problem. The markets have probably not yet felt all the influences which this large production of crops is likely to exert. Scrap, pig iron and billets may within a few months be found in new relations with each other. The measure of production is the capacity of the open-hearth furnace, and if all the crops are charged into the furnace, together with other scrap produced by the mill, the supply of scrap otherwise drawn from the mill is not required, and even the consumption of pig iron may be curtailed. Open-hearth steel billets are now very scarce, but if the crops should find their way largely into billets this situation might be very markedly altered. The situation merely presents possibilities. The specifications vary greatly with different orders and the various mills that have accepted the orders may work out their problems in very different ways.

Readers' Views and Comments

The Potash Situation

To the Editor of Metallurgical & Chemical Engineering:

Sir: Mr. Dolbear, in his instructive article on the potash situation in your August number, apparently overlooks altogether the only potash resource in the United States that at present promises to produce potash to any extent at an early date.

The Searles Lake project in Southern California is unfortunately slow in its development, and the other prospective potash sources mentioned are none of them being worked on a scale much beyond the experimental, if they are worked at all.

The potash source which Mr. Dolbear has overlooked is the alunite deposits in Utah. These promise to deliver at an early date a marketable soluble potash salt.

Alunite, being an insoluble hydrous potassium sulphate, can readily be dehydrated and partly decomposed by calcination. In doing this the water is driven off and the aluminum sulphate is decomposed, leaving insoluble aluminum oxide and the soluble potassium sulphate.

Active development work is going on in the alunite deposits in Utah. New veins are being found, and one mill is under construction, and still a couple of others are projected, and the construction of these is expected to start at an early date.

The mill in which the ore is to be calcined, now under construction, is owned by the Minerals Products Company of New York City, and it is generally understood that the products from the mill will be disposed of by the Armour Company.

One hundred tons of alunite per day the plant is planned to take care of, and this amount of alunite will, on calcination, produce twenty tons of potassium sulphate, and thirty-seven tons aluminum oxide.

Considering the total consumption of potash per year in the United States for fertilizer purposes, it is apparent that twenty tons per day is only a very small fraction of the total fertilizer needs of the country, but, at the same time it certainly indicates a good start, and the existence of a domestic source of potash readily made available.

The aluminum oxide obtained in the calcining of the alunite is a by-product, and contains about 99 per cent of Al_2O_3, and approximately 1 per cent of impurities, such as silica and other metallic oxides.

This aluminum oxide can with slight expense and with some care be further purified, and in such condition it may be used in the manufacture of metallic aluminum.

The output of aluminum oxide from even a moderately sized potassium sulphate plant would be considerable, and if all the oxide of this first installation were reduced into metal, some eighteen tons of aluminum would be produced daily, or close to one-fifth of the total aluminum production in the United States per day during 1913.

The thought has been launched that by obtaining this aluminum oxide as a by-product at practically no cost it would be feasible to manufacture aluminum so cheaply that it could be sold at such a low price that the usages for aluminum would be very materially broadened.

The potash situation could well be considered alarming at present in the United States, with the German supply altogether eliminated, but fortunately there are stored enormous quantities of potash all through the country.

It is unfortunate that the chemical combination in which the potash occurs is, with the exception of alunite, such that it involves considerable amount of expense and labor to obtain it in a soluble condition.

There are many processes evolved for the purpose of making these potash resources available, but so far none has been successful enough to justify its operating on a scale much beyond the experimental stage.

This does not eliminate the possibilities that all the potash stored in the Lencite Hills in Wyoming and in the feldspathic rock deposits all through the country cannot be made available at an early date, but it is "up to the chemists" of the country to economically sever the pernicious hold silica has on the much needed and coveted potash.

It has struck me that the chemical profession could in no better way serve our country to-day than assist in solving the potash situation, expedite the liberation of the fettered potash which in reality represents our nation's daily bread, and possibly in years to come the daily bread of many of our European neighbors.

To accomplish the expeditious solving of this problem, I ask you whether a joint committee could not be formed among the leading chemists of the United States, immaterial if they belong to any chemical societies or not, for the purpose of discussing this matter and evolving methods by which to accomplish this. The co-operation of the people and the Government of the United States could certainly be counted upon, financially as well as otherwise.

Any valuable inventions made and processes developed by this committee should be patented, but these patents would all be turned over to the United States Government, making the use of patents and processes free to everybody.

The successful solving of this problem at this time, under these conditions, would build a monument to the chemical profession which time could never obliterate.

J. W. Beckman.

San Francisco, Cal.

Repairing Furnace Linings with Compressed-Air Gun and Torch

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In your issue for April, 1915, page 250, I note reference to my patented process for forming and repairing furnace linings by means of a compressed-air gun combined with a torch, the object being to form a dense vitrified lining. As I am not financially interested in this patent in any way my opinion on the process may be considered unbiased. The idea of using a compressed-air gun to project materials into a furnace is not new; but from my experience with processes I have come to realize that there is a vast difference between ideas and their practical application. I have built and operated reverberatory furnaces and it was for this reason that it occurred to me, while I was engaged in some engineering work for the Cement Gun Co. that their machine could be used for the purpose indicated above. In my connection with the Cement Gun Co. I had an opportunity to study the development of the machine from the time it was first conceived by Mr. Ackley up to its present development, and I would say that the idea of blowing a solid against a surface is one thing and carrying out the idea is another.

Volumes could be written on the difficulty of doing

that very thing, and I myself have spent the better part of two years in solving the problems connected therewith. It can, therefore, be very easily understood that anyone merely wishing to apply this idea to furnace work, without having knowledge gained from experience, would run against great difficulties in a mechanical way. This is probably the reason why the matter has never been prosecuted farther.

A furnace built by this process whereby the proper screen combination is used to produce a mixture which can settle into place with practically no voids, would give enormous metallurgical advantages. The absorption of the bottoms would be reduced to a minimum, and with it, of course, the necessity of smelting old bottoms and placing new ones would be reduced in proportion. The furnace up-keep can not only be reduced to a low cost, but a furnace can be made to last practically indefinitely, because an absolute bond can be obtained between the material in place and the new material, and repairs can be made without interfering with the operation. Thus, if the proverbial "stitch in time" is applied whenever needed, the furnace should be kept constantly in first class repair with very little cost. If anyone wishes to try this process and is willing to go into detail, I would be glad to furnish any advice I am able to give as to details of operation.

Joplin, Mo. ALFRED SCHWARZ.

Metallurgical and Chemical Engineering in Great Britain

(By Our London Correspondent)

Concerning Things in General

All mental and industrial activity here (in London) is now dominated by one thing, and one thing only. The war and the demands incidental to it determine not only civilian occupations and movements, but our diverse pre-occupations. We talk very little about what we shall do when the war is done—although perhaps we are doing more "thinking ahead" about commercial and economic matters then than we were wont to do in the easy days when in their relentless, inevitable but unsuspected ways, uncontrollable forces were insuring the advent of a colossal war.

We are now mainly preoccupied with a very big problem—the national regrouping and reorganization of all activity. Save for those who wear the king's uniform here or in the field, there are before us here many questions centering round the fact that we must either answer them successfully or make way for a race with the brain to translate the co-ordinated activity of the anthill or the hive into the every-day facts of existence and racial persistence.

Individualism has played its part, and a very valuable part, in our development hitherto, but there has been a nemesis of individualism. When every man does "what seemeth right in his own eyes" without regard to discipline grave risks are run. Equally, too, superorganization with the elimination of individual thought or initiative has in it all the potentialities of atrophy and decay. Modern Germany, with all its wealth of organized knowledge, yet suggests in some degree a feeble imitation of the complex and highly organized civilization of the Incas. Safety obviously lies in avoiding the pitfalls on either side, and possibly some of its innate inclination for compromise will help the British race to surmount its obstacles.

The manufacture of rifles, field guns, cartridges, high explosives, aeroplanes, boots, uniforms, vehicles, and the feeding of the army is only one of many problems. The transport of men and munitions must be carried on simultaneously with the transport of foodstuffs and raw materials for the civil population. Military activity alone cannot suffice for any race barring, say, a race of freebooters content with an ephemeral existence of short but not necessarily jubilant span. Civilization demands synchronism between military effort and non-military activity when everything is referred to the arbitrament of the sword.

We are improvizing as we go along, and reckon to make a success of our improvization, although the cost of improvization will give us a bad national headache when the show is over.

Writing in a khaki uniform, one hesitates to prophesy. Yet your correspondent feels constrained to make a duplex prophecy which will fit either event that the fates yield to Europe. If militarism triumphs, it will be morally conquered by the adoption of a part of the individualism of the conquered nations. If the individualist and hitherto non-militarist races come out on top they, too, will be morally conquered by their adoption of semi-militarist tendencies and by an imitative co-ordination and national organization of the industrial activity of the race which they must now break or else be themselves broken.

Metallurgical Work at the National Physical Laboratory 1914-1915

The annual report of the National Physical Laboratory, now in my hands, is a chronical of diverse activities, all more or less influenced by the war. Twenty-five per cent of the staff—some fifty members—are now on military service, some of them in the same corps as your correspondent, doing similar garrison duties. Of course, the financial results of the year's work at the laboratory have been adversely affected by the war. Up to the end of June, the receipts for work done were considerably in excess of those for the corresponding three months of last year; during the next three months there was a heavy fall, amounting to some £2,100, but subsequently there has been a considerable recovery, the net result is that the accounts show a credit balance of £80.13.8.

So far as the present letter is concerned, I propose only to refer to the report of the department of metallurgy and metallurgical chemistry, leaving other matters for a later letter.

New apparatus has been added, including (1) a new vacuum pump—Gaede's piston type—for use in connection with the research on the melting point of iron in vacuo; (2) a large induction coil, intended primarily for use in connection with the cathode-ray furnace; (3) the remodelling of the plotting chronograph; (4) a microscope levelling device intended to supersede the older mechanical devices for setting the prepared surface of the specimen at right angles to the optic axis of the microscope; (5) an experimental rolling mill. This mill has been designed primarily for the purpose of providing facilities for rolling ingots of light alloys (alloys of aluminium) into bars and sheets for the purpose, in the first place, of ascertaining the suitability of various alloys for mechanical use, principally in connection with aeronautics, and, in the second place, for the purpose of determining the exact conditions under which various promising alloys can be rolled in a satisfactory manner. The mill, however, has been so designed that other alloys can also be handled in it. The need for an experimental equipment of this kind has arisen, in the first instance, from the circumstance that it has been found very difficult to obtain satisfactory rolling results in existing industrial mills with certain alloys which showed a high promise of usefulness. Although several bars of such alloys have been rolled by using extreme care and special precautions, it was quite

obvious that industrial success could not be obtained until the exact conditions demanded by the peculiarities of these alloys had been thoroughly studied. By equipping a full size rolling plant, in which the various conditions of speeds, draft and temperature are under exact control, it will be possible to ascertain within what limits these various factors must be kept in order to secure uniformly successful production. Experience has already shown that the conditions suitable for the rolling either of pure aluminium or of brass or steel are not satisfactory for these new materials.

Apart from these special questions, the rolling mill equipment promises to be of particular value for facilitating research on many questions connected with this important manufacturing process, since measurements of power, temperature, etc., can be carried out in the laboratory plant in a manner quite unattainable in most existing industrial establishments.

As regards research work, this was almost entirely confined to the first three or four months. After the outbreak of the war, this department was so short handed that it was found difficult to do much more than cope with the investigatory test work. The work actually done referred to the constitution of the Aluminium Zinc-Copper series. Considerable difficulty has, however, arisen in interpreting the indications of thermal curves and of microscopic examination relating to the alloys lying near the aluminium corner of the ternary triangle. This difficulty has now been traced to the fact that the accepted constitutional diagram for the copper aluminium alloys containing 90 per cent of aluminium and over is incomplete in regard to an important reaction which occurs in the alloys at a temperature of 560 deg. C. It has, however, been found difficult to discover the exact nature of this reaction, and since it is of fundamental importance to the understanding of the ternary alloys containing up to 5 per cent of copper, considerable time has been devoted to the study of this special point. This difficulty is an example of a class which is frequently met with when ternary alloy systems come to be investigated in an accurate manner. It is then frequently discovered that a very minute transformation which occurs in one of the binary systems has escaped observation, but that the evidences of this occurrence, such as thermal arrest points and microscopic changes, become considerably intensified by the addition of a few per cent of the third metal. Although in themselves of considerable interest, the discovery of these points often requires a very extensive investigation before the work on the ternary system can proceed satisfactorily, so that the labor—already very extensive—of investigating ternary systems is thereby very largely increased. It is, however, considered that the studies of ternary systems undertaken at the laboratory should not be merely of an approximate or exploratory nature, but the full treatment necessarily involves considerable delay in the attainment of results suitable for publication. This is the principal reason why it has not been found possible to issue a further alloys research report during the past year. It is hoped, however, to carry the work to a stage where publication becomes possible before the end of the present calendar year.

Experiments on the physical properties of the ternary alloys have been largely postponed until the rolling of the alloys could be carried out in the experimental roling mill at the laboratory itself. A large number of ingots for the purpose of carrying out these rolling experiments have, however, been prepared, and as soon as the equipment of the mill is complete a large quantity of results will rapidly become available.

The scheme for the extended investigation of the permanence of light alloys in regard to supposed spontaneous disintegration, which was set out in the previous report, has been steadily pursued as far as the adverse circumstances already noted have permitted. The preparation of the very large number of test pieces has proceeded and is now approaching completion, while a considerable number of measurements have been made.

Other research work has included some work on low carbon steel as to the effects of strain at high temperatures, on the intercrystalline cohesion of metals, on the melting point of iron. With reference to Dr. Rosenhain's new re-agent for etching steel, it is pointed out that an example of the usefulness of this re-agent has recently occurred in connection with steel required for war materials. In this steel, minute cracks and fissures, which inevitably led to the rejection of the final product, have been found to be definitely associated with the presence of phospheric bands, whose presence was clearly revealed by the re-agent. A further interesting observation, which has been carefully confirmed, illustrates the manner in which the phospheric banding of steel persists even after drastic heat treatment. This observation was made by examining a banded steel in the ordinary annealed condition and again after quenching from 800 deg. C. In the latter condition, while the bulk of the steel was in the condition of martensite-troostite, certain regions were found to consist of ferrite, and this could readily be identified with the bands of phospheric ferrite revealed by the new re-agent in the annealed steel. This observation shows clearly how the presence of a relatively high proportion of dissolved phosphorus prevents the diffusion of iron carbide even at a temperature as high as 800 deg. C. A further inference may be drawn to the effect that the presence of marked phosphorus banding is a very serious disadvantage to steels which have to be hardened, and incidentally also to materials intended for case hardening, since phosphoferrite resists diffusion of carbon, and this leads to the production of soft spots, and even of cracks, after hardening.

Reference is also made to the Research on Magnet Steels conducted under the auspices of the Research Committee of Magnet Steel.

A detailed study of the constitution of the Alloys of Copper and Tin has been begun with a view to utilizing the most accurate available methods for clearing up the points which still remain in doubt in regard to the constitution of these alloys.

The work so far undertaken has dealt with alloys containing 55 to 65 per cent of tin, and the results have been published in a paper read at the March (1915) meeting of the Institute of Metals. Incidentally, for the purposes of this research, a new form of thermostat has been developed (Mr. Haughton and Mr. Hanson), which allows specimens to be annealed in electrically heated furnaces for long periods at a temperature maintained constant within + 1 deg. C. As yet the apparatus has only been constructed of glass, and is, therefore, only available up to a temperature of about 450 deg. C., but it is hoped to extend its usefulness by having it constructed in silica, or, possibly, even in metal. It will then be very useful in the metallographic study of many alloy systems.

There has been much activity in regard to investigatory test work. The work which has been carried out may be roughly divided into three groups:

(1) Investigation of cases of failure.

(2) Investigations in connection with manufacturing processes, the manufacture of specific articles, or the use of special materials.

(3) Investigations connected with aeronautics.

Cases coming under group (1) have been more numerous than usual. The examples dealt with cover a very wide range of metals (ferrous as well as non-ferrous)

and a wide range of objects. As regards group (2), while several of the cases ivestigated have been those arising out of industrial difficulties of an ordinary nature, several have arisen, during the last few months from circumstances due to the industrial conditions caused by the war. The laboratory has been, in several instances, in a position to overcome the difficulties of manufacturers arising from shortage of customary materials, etc. Owing to the confidential character of the work of this kind detailed reference to it is obviously impossible.

The investigation of failures and breakages occurring in connection with aeronautical work, principally in regard to engine parts and in some cases structural parts of aeroplanes, has occupied a very large amount of time and attention from the superintendent and staff of the department. Particular attention has been devoted to the question of the effect upon steel of acetylene welding, and the research which has been undertaken in consequence of the questions raised in this connection is being carried out jointly with the engineering department. The materials involved in these aeronautical questions are in many cases special alloy steels of peculiar properties and microstructure. The peculiarities in question have in many cases required special experimental investigation; so much so is this the case, that it is becoming desirable that a systematic study of the more usual types of alloy steels should be undertaken by the department, and, as indicated in the outline program for future work, it is hoped to undertake such a systematic study as soon as the pressure of the work of the staff of the department may permit.

Market Prices

JULY, 1915

Copper opened at £82, and fell rapidly to £79.10 (2nd), recovered to £80 (6th), then declined to £78 (12th), and after a slight improvement to £78.10 (13th), it fell away to £74.15 (18th); it then rose to £76 (21st), and after declining to £75 (23rd), fell sharply to £72 (25th), recovered slightly to £72.10 (26th), and continuing to fall closed at £71.10.

Tin opened at £172.10, falling to £171 (2nd). It then improved to £173 (3rd), declined to £170.10 (8th), and after again touching £173 (13th) fell rapidly to £165 (20th). After a slight recovery to £166 (21st), it continued to fall steadily, closing at £155.

Haematite opened at 95/- and remained at this price throughout the month.

Scotch Pig opened at 72/6, improving to 74/- (7th). It then declined, again reaching 72/6 (20th), and after recovering slightly to 73/- (22nd), continued to fall to 72/3 (27th), after which it remained fairly steady, closing at 72/6.

Cleveland opened at 66/6, improving to 67/6 (2nd). After a slight decline to 67/3 (3rd), it continued to rise to 68/- (7th). It then fell slowly again, reaching 66/6 (20th), recovered to 67/- (22nd), but afterward lowered to 66/3 (27th). It then improved slightly, closing at 66/6.

Lead opened at £26.15, and after falling away to £25 (8th), it recovered to £26.5 (26th), at which price it remained steady till the 15th; it then declined to £25.15 (16th), and again remained steady till the 24th, after which it continued to fall, closing at £24.10.

	£	s.	d.
Borax, per ton	22	0	0
Copper sulphate, per ton	28	0	0
Caustic soda, 70 per cent, per ton	10	2	6
Hydrochloric acid, per cwt		4	6
India rubber, Para, fine, per lb		2	6½
Mercury	18	10	0
Sal Ammoniac per cwt	48	0	0
Shellac, per cwt	3	5	0
Platinum, per oz	9	5	0
Ebonite rod, per lb		3	0
Sulphur, sublimed flowers, per ton	11	10	0
Mica in original cases, medium, per lb		5	0

Notes

Electrolytic Oxygen and Hydrogen.—The International Oxygen Company, 115 Broadway, New York City, has issued a 24-page booklet on "I. O. C. System, Production Pure Oxygen and Hydrogen." It deals with the I. O. C. system of welding and cutting and is profusely illustrated, showing installations in various parts of this country and abroad.

Converter practice at Hayden, Ariz., has given the following results, according to Manager J. J. Ormsbee: Throughout November, 1914, a daily average of over 81 tons of copper was produced from a 42 per cent matte, with a standard size Pierce-Smith converter. During the first half of February, 1915, a daily average of 85 tons was maintained.

The Dome mill, at Porcupine, established a new record in May, when 26,000 tons of ore was treated, having an average value of $4.28. The gold produced was valued at $111,261. This tonnage is the largest in the history of the mill; the value was approximated in April, when it was $4.20 per ton.

The Ohio Copper Company's mine and mill at Bingham and Lark, Utah, have been leased to the General Exploration Co., of Salt Lake City. The mill will be put in condition to handle 2000 tons of ore daily.

Stratton's Independence, Ltd., treated during the month of April 8387 tons of low-grade dump and mine ore, netting the company $8,000.

Porcupine Crown Gold Mining Co. is preparing to retreat the tailings from its experimental amalgamation mill. The dump contains about 19,000 tons valued at $3.50 per ton, and was accumulated prior to the erection of the cyanide mill.

The Tropenas Converter Co., of 50 Church St., New York, is erecting a new office and laboratory building of its own in Brooklyn, N. Y. This will include a small experimental plant in which a novel steel-producing method is to be perfected.

The Bucyrus Company, of South Milwaukee, Wis., has moved its Southern sales office from Birmingham to New Orleans, La. Mr. E. L. Byron, Southern sales manager, will remain in charge, and will have associated with him, Mr. R. S. Byron. His office will be 1105 Hennen Building.

The price of ferromanganese in the United States fluctuated widely in 1914, on account of the European war. Prior to August the price of standard 80 per cent ferromanganese was about $40 a long ton. During August prices ranged from $110 to $140 a ton, while quotations dropped as low as $62 in November and advanced again to $80 in December.

The establishment of platinum refineries in Russia has not been encouraged as a result of the order forbidding the exportation of platinum in quantities valued above 500 rubles ($257.50). Not a single refinery has been opened, and producers find themselves with large quantities of metal on hand which they cannot market. The bureau for gold and platinum industries has been asked to ascertain whether sales can be effected in this country, and if so the producers will ask for a modification of the embargo. Representatives of the gold mining industry in Russia have petitioned the government for the establishment of a concern to manufacture potassium cyanide.

Tanks.—The Walter A. Zelnicker Supply Company of St. Louis has sent us its recent bulletins on used tank car tanks.

The Link-Belt Company, of Chicago, has issued its new Portable Wagon Loader Catalog 210, which de-

scribes the machine that will load a wagon or truck with material carried on the ground at the rate of one ton per minute.

Gas and Gasoline Engines.—The Chicago Pneumatic Tool Co. has issued a bulletin describing their class A-G Giant Engines for the utilization of natural or producer gas or gasoline.

DeLaval Centrifugal Blowers and Compressors are described in a catalog recently issued by the DeLaval Steam Turbine Company of Trenton, N. J. This is a profusely illustrated catalog containing illustrations, diagrams, and descriptions of their products.

The Mesta Machine Company of Pittsburgh reports a recent shipment of a four-arm low-type sheet pickling machine to the Alan Wood Iron and Steel Co., Philadelphia, and orders from the McKeesport Tin Plate Company for three of these machines.

Costs in the Steel Foundry is the title of Steel Castings for July, 1915, a small bulletin issued by the Tropenas Converters Company. This bulletin discusses costs systems and gives special attention to overhead costs and the determination of selling prices.

The Snyder Electric Furnace Co. of Chicago is installing a Snyder steel furnace for the Canadian Brakeshoe Company, Ltd., of Sherbrooke, Quebec. This furnace will melt and refine cold material and will deliver 24 tons in 24 hours.

Glass Enameled Products.—The Elyria Enameled Products Company of Elyria, Ohio, has issued Catalog *B* describing seamless one-piece enameled apparatus. This includes open and closed tanks, steam and water jacketed kettles, vacuum pans, etc. The glass enamels used are claimed to be acid, alkali, and rust resistant, and the seams are welded by the autogenous welding process.

The National Screen Separator is described in a bulletin recently issued by the National Engineering Co. of Chicago. The feature of this separator is a device for keeping the screen from clogging up. This is accomplished by having wires stretched underneath the screen which are alternately drawn taut and released by suitable mechanism, thus forming a vibrating devise striking the screen.

Conductivity of Electrolytes.—The accurate measurement of the conductivity of electrolytes is discussed, and improved apparatus for this purpose described, in catalog No. 48 recently issued by the Leeds & Northrup Company, Philadelphia, Pa. The development of this apparatus was made with the assistance of Dr. E. W. Washburn of the University of Illinois. The catalog contains, besides the description of apparatus, much valuable technical information on conductivity measurements, comprising about 29 pages of discussion, diagrams and illustrations.

The **National Tube Company**, Pittsburgh, Pa., has issued Catalog J, comprising material manufactured at the Kewanee Works of the National Tube Company, embracing "National" pipe for steam, gas, water and air; cast iron, malleable iron and brass fittings; "Kewanee" unions and "Kewanee" specialties; brass and iron body valves and cocks; radiators and coils; drive well points and well supplies. The catalog is a beautifully illustrated volume of 394 pages, and very elaborate and detailed in its information, giving lists of the different sizes of the materials manufactured, with drawings and in part colored illustrations.

The debt of Chilean nitrate producers to the government on May 15, as a result of loans advanced by the government to keep the industry going, amounted to $2,880,000.

Ultraviolet Rays.—A reference list of 317 articles, etc., on ultraviolet rays, available in the New York Public Library has been published in form of a pamphlet by this Library.

The output of recoverable zinc in New Jersey in 1914 was 148,506,500 lb., as compared with 144,312,560 lb. in 1913. Owing to the lower average price of spelter, the estimated value of the 1914 product was only $7,515,914, as against $8,081,502 in 1913.

Antimony shipments from Central China during the first three months of 1915, according to the Hankow *Times*, consisted in 1067 tons of antimony regulus and 2560 tons of crude antimony. The price for regulus has practically quadrupled since last August, and the high price has greatly stimulated production.

The production of Portland cement in the United States in 1914 was 88,230,170 barrels, valued at $81,789,368, according to the U. S. Geological Survey. The output represented a decrease in quantity of 3,866,961 barrels, and a decrease in value of $10,768,249, as compared with 1913.

A Government Corner in Chinese Blue.—According to a Washington newspaper story, Mr. Joseph E. Ralph, director of the Bureau of Engineering and Printing, has bought up in New York all the available supply of Chinese blue and other special colors needed in the preparation of stamps, seals and paper money.

Methods of determing total sulphur in rubber have been studied by the Bureau of Standards. The results have been published in Technologic Paper No. 45, recently issued. Copies may be had free of charge on application to Bureau of Standards, Department of Commerce, Washington, D. C.

The ash of the seaweed collected on the shore of Manila Bay in Tondo is reported to yield 15 per cent of potash. No data are available to show the quantity of seaweed that can be gathered, but it is considered to be abundant. The discovery has aroused considerable interest owing to the present scarcity of potash.

The American Shop Equipment Co. of Chicago has issued a bulletin on Shop Furnaces describing their rivet forges for oil or gas fuel, flue welding furnace and forge furnaces, also heat treating furnaces and pot furnaces, all for oil or gas fuel. The bulletin also gives complete export shipping data.

The Hardinge Conical Mill Co. is installing for the Nevada Consolidated Copper Co. two 8-feet dia. Hardinge mills, to be used with iron balls. Also an order from the Dome Mines Co., Ltd., of South Porcupine, Ont., Canada, for two 8-feet dia. ball mills. These ball mills are to take the place of stamps now in use at the Dome Co.'s plant.

The **Superior Chemical Corporation** has recently been organized, with factory and office at 170 Tillary Street, Brooklyn. The officers are John E. Muhlfeld, president, and Samuel G. Allen, secretary and treasurer. The operation of the plant will be under the supervision of J. L. Danziger. The company will manufacture chemical and allied products, with especial attention devoted to photographic developers.

Natural Gas.—The Bureau of Mines has just issued Technical Paper 109, which deals with the chemical and physical properties of the natural gases used in twenty-five cities in the United States. The authors are G. A. Burell and G. G. Oberfell. Five of the samples contain methane only, as the combustible gas. The others contain in addition to methane higher members of the series of paraffin hydrocarbons. The heating values range from 735 to 1312 B.t.u. per cubic foot at 0 deg. C. and 760 m.m. pressure.

Copyright by Detroit Publishing Co.

Seattle Meeting of the American Chemical Society

THE fifty-first meeting of the American Chemical Society was held at Seattle, Washington, from Tuesday, Aug. 31, to Friday, Sept. 3, and proved unusually successful and enjoyable. It was a somewhat "old-fashioned" meeting in the best sense of the word, with a preponderance of general meetings over sectional sessions, with the attendance always held well together, and a true, congenial happy spirit prevailing all around.

Immense credit is due to the local committees, with chairmen H. G. Byers of the executive committee, H. K. Benson of the finance committee, E. J. Bartels of the excursions committee, L. A. White of the press committee, J. H. Linton of the reception and registration committee, R. W. Clough of the banquet committee, M. J. Falkenberg of the smoker committee, and Mrs. C. A. Newhall of the ladies' committee. With Seattle extending its fullest hospitality to the society everyone felt at once at home. But for the fine and truly happy spirit which prevailed full credit must also be given to the president of the American Chemical Society, Dr. Charles H. Herty, who impressed his charming personality on the whole meeting and even succeeded in eliciting some excellent and lively discussions in the technical sessions.

The attendance during the general meetings was nearly 200. From the East a party of about forty members had come in a special car personally conducted by President Herty and Secretary Parsons. A stay at Glacier National Park on Saturday and Sunday, preceding the Seattle meeting, was delightful. The party arrived at Seattle on Monday. Simultaneously another party of a score of members arrived in countercurrent from San Francisco, having attended the meeting of the American Institute of Chemical Engineers the week before.

On Monday night there was a meeting of the council of the American Chemical Society, preceded by a complimentary dinner. The general meeting started on Tuesday morning in the chemical laboratory of the University of Washington with general registration. The registration officials were not only charming to look at, but the office had a 100 per cent efficiency as a semipermeable diaphragm. Members having registered and received the very pretty totem-pole badges found themselves in the lecture room, with no way left to the outside. And the meeting that followed was enjoyed by all in fullest measure.

Open Meeting

The meeting was opened by Dr. H. G. BYERS, professor of chemistry at the University of Washington. He introduced Dean ARTHUR PRIEST, who as personal representative of the president of the University and of the Mayor of Seattle extended the welcome of university and city to the society in a felicitous little speech.

Dr. CHARLES H. HERTY, president of the American Chemical Society, in his reply referred to the reception which the society had from the Seattle section five years ago on its Western trip. He spoke of the Pacific Coast as a land that has been built by "boosters" in the best sense of the word. The confidence in the future of this country is our rich inheritance from the pioneers who built up the empire at the Pacific Coast. Dr. Herty paid a tribute to the daily newspapers of Seattle which show so much interest in science and industry in general and in the University of Washington in particular, and as newspapers give the people what they want, this fact proves the great interest which the people of the State of Washington take in their University. Dr. Herty concluded with a reference to the great developments right before us now and the immense opportunities of the American chemist. Mutual helpfulness must be the keyword.

CHEMICAL INDUSTRY

The opening address related to "Chemical Industry," the author being Dr. L. H. Baekeland. In his absence the address was read by the secretary, Dr. Parsons. As this address is to be delivered again next week by the author himself in connection with the National Exposition of Chemical Industries, in New York, we reserve its publication in full to our next issue.

Dr. Baekeland referred to the present European war as a chemists' war. But "do not imagine that this is the first chemical war. The art of kiling and robbing each other became chemical the day gun powder was invented; at that time, however, the existing knowledge of chemistry was just of pinhead size. Napoleon knew very well how to use adroitly exact knowledge and chemistry for furthering his insatiable ambition to dominate the world; so he surrounded himself with the most able chemical advisers and scientists. Ever since then science, technology and chemistry in particular have played a rôle of increasing importance in the armament of nations. . . .

"Do not reproach chemistry with the fact that nitrocellulose, of which the first application was to heal wounds and to advance the art of photography, was stolen away from these ultrapacific purposes for making smokeless powder and for loading torpedoes. Do not curse the chemist when phenol, which revolutionized surgery, turned from a blessing to humanity into a fearful explosive, after it had been discovered that nitration changes it into picric acid.

"Let us hope in the meantime that war carried to its modern logical gruesomeness, shorn of all its false clamor, deceptive picturesqueness and rhetorical Bombast, exposed in all the nakedness of its nasty horrors, may hurry along the day when we shall be compelled to accept means for avoiding its repetition."

After his introductory remarks on the war, Dr. Baekeland reviewed the peaceful work of the chemists in the industry, especially the work of the American chemists who, he emphasized, are a more potent factor in the world's progress now than those of Germany or England. He emphasized the importance of the achievements of American electrochemical industries, compared with which the dyestuff industry is almost insignificant. He defended in a strong and able manner the American chemist against the claim that he was to be blamed for the lack of an American dyestuff industry.

But Dr. Baekeland also agreed that in the past, chemists, as a general rule, had been too much analytical and not enough constructive. "Successful engineering is essentially constructive. The most urgent work for the chemist of to-day must be constructive—he must learn how to cement together the vast amount of data which already lie at his disposal, even if he, himself, has to produce this very cement by further research."

THE PACIFIC NORTHWFST

Dr. H. K. Benson, of the University of Washington, followed with an address on the "Industrial Resources and Opportunities of the Pacific Northwest." This address is published in full at the end of this report.

SYMPOSIUM ON THE CONTRIBUTIONS OF THE CHEMIST TO VARIOUS AMERICAN INDUSTRIES

After these two addresses of general interest, the symposium of papers on contributions of the chemist to various American industries was taken up, in continuation of the series of papers presented at the New Orleans meeting (this journal, May, 1915, p. 283).

John E. Teeple's paper on "The Contributions of the Chemist to the Naval Stores Industry" was read by Professor Frankforter.

George W. Sargent's and A. L. Cushman's two papers on "The Contributions of the Chemist to the Iron and Steel Industry" were read by Professor Franklin.

M. H. Ittner's paper on "Contributions of the Chemist to the Art of Soap Making" was read by Dr. Richardson.

E. T. Beiser's paper on "Contributions of the Chemist to the Perfumery Industry" was read by Dr. Byers.

G. W. Thompson's paper on "Contributions of the Chemist to the Lead Industry," was read by Professor Withrow.

Maximilian Toch's paper on "Contributions of the Chemist to the Paint and Varnish Industry" was read by Dr. Parsons.

Dr. John R. M. Klotz, chief chemist of the Barrett Manufacturing Company, then presented a very interesting paper on "Contributions of the Chemist to the Coal Tar Industries," which we reserve for publication in full in our next issue. This paper elicited an extended and lively discussion in which Dr. Klotz gave additional information on the particular conditions of this industry created by the war.

Mr. R. F. Max Michael then read an illustrated paper on a new viscosimeter.

The balance of the program for this afternoon comprised the following three papers:

Francis C. Frary, "Contributions of the Chemist to the Photographic Industry."

Frank R. Eldred, "Contributions of the Chemist to the Pharmaceutical Products Industry."

S. W. Katzenstein, "Contributions of the Chemist to the Hardwood Distillation Industry."

Sessions of Wednesday

While the afternoon of Wednesday was devoted to section meetings, the forenoon was given over to a very interesting symposium on wood distillation in general session.

Professor James R. Withrow of Ohio State University gave an illustrated lecture on "Chemical Engineering Features of the Hardwood Distillation Industry. Dr. S. F. Acree of the Forest Products Laboratory of Madison, Wis., discussed "What Chemistry Had Done to Help the Utilization of Wood."

The other papers on the program for this session were:

H. K. Benson and T. G. Thompson, "The Study of the Tannin Content of Douglas Fir Sawmill Waste."

H. K. Benson and Marc Darrin, "Yield of By-Products from the Destructive Distillation of Some Western Conifers."

H. K. Benson and Newton Crites, "The Extraction of Resinous Wood by Ammonia."

Roy C. Judd, "Discoloration of Maple in the Kiln."

R. E. Rose and A. G. Bissell, "The Chemical Composition of the Light Oil from the Destructive Distillation of Resinous Woods."

F. W. Kressmann, "Manufacture of Ethyl Alcohol from Wood Waste. II. The Hydrolysis of White Spruce."

Homer Cloukey, "The Application of the Davis Spot Test in the Preliminary Examination of Creosotes."

A. W. Schorger and Ralph Sayre, "Isoprene from Beta-pinene."

Bailey Tremper, "The Distillation of Douglas Fir at High Temperatures."

F. W. Kressmann, "The Manufacture of Ethyl Alcohol from Wood Waste: III Western Larch as a Possible Raw Material."

Marc Darrin, "The Production of Acetone from Pyroligneous Acid."

An account of this symposium is reserved for our next issue.

PRESIDENTIAL ADDRESS

Dr. CHARLES H. HERTY'S presidential address on "Co-operation in Matters Chemical," delivered on Wednesday evening, was one of the ablest presidential addresses delivered before the American Chemical Society.

Dr. Herty pointed out how regrettable it was that the three-year-old determination of international co-operation of chemists, conceived at the International Congress of Applied Chemistry in New York City in 1912, had so early been forgotten, due to the war.

Research, whether "pure" or "applied," is identical. Pure enrichment means enrichment of the soil, applied research means crop production. There is no dignity or lack of dignity involved. "Pure" and "applied" research are just terms of convenience.

Dr. Herty emphasized the responsibility of professors of chemistry in universities, especially head professors, in bringing out the national point of view, through their attitude toward research.

The war situation has called public attention too acutely to certain special applications of chemistry, at the expense of the deserved appreciation of the quiet workers who have in the past built up our science.

Dr. Herty made a plea to all chemists for some little research with no hope of pay so that all of us may thus repay our obligation to our science.

University research should be greatly encouraged. This raises the question whether there exists the proper co-operation between the universities and the industries.

Do university professors have the proper attitude toward the problems of the industry? Do they emphasize sufficiently "chemistry in service of mankind?"

On the other hand, do men in the industries appreciate properly the rationale of the university professor's point of view in establishing fundamental facts and drawing accurate deductions therefrom?

Dr. Herty emphasized the stimulating and broadening influence of the general meetings of the American Chemical Society held in different parts of the country. He warned against the dangers of local sectionalism in the society.

Chemical preparedness for national defense puts an important responsibility upon the chemist, who derives in return the valuable benefit of the proper development of certain needed industries which might otherwise be neglected.

That the nation should be self-contained is a matter of most fundamental importance.

Our visible supply of sodium nitrate is slight. We have depended too much on Chile saltpeter and perpetual peace. We should acquire, with government help, a sufficient supply to tide us over an extra year until factories could makes nitrates from air in case of war.

Ammunition is important enough, but have we acquired chemical preparedness in industrial chemistry?

Dr. Herty then discussed our patent system and where it is deficient. He called attention to the failure of the nation to understand the asset value of a patent and to the failure to protect him who creates. The nation, through its laws, should be the guardian of the patentee.

Dr. Herty mentioned the throttling of the early aniline oil industry in this country by foreign competition. He emphasized the viciousness of dumping and the necessity of the adoption by Congress of an anti-dumping clause.

Dr. Herty pointed out the value which an American dyestuff industry would have as a reserve for the explosive industry.

In concluding his able analysis of the present industrial chemical situation in this country, Dr. Herty emphasized that the chemist has made good. What we need is wise legislation.

Social Functions and Entertainments

The entertainment program was delightful.

The special program for the ladies contained an extensive automobile trip, a theatre party, and a fine exhibition of folk dances by co-eds of the university.

The Council was entertained at a complimentary dinner on Monday night.

The feature of the smoker given to the Society on Tuesday evening at the Seattle Commercial Club was an illustrated lecture by Professor Edmond S. Meay, president of the Mountaineers, on Mount Rainier. There were also some vaudeville entertainments and the whole occasion was greatly enjoyed.

On Wednesday afternoon there were automobile rides, on Thursday a fine excursion on Puget Sound for the inspection of the shipping and fishing industry, and a banquet in the evening of Thursday. As the writer had already left Seattle, he is unable to say from his own experience how the following feature of the banquet program, quoted from the Seattle *Daily Times*, worked out: "So that the local chemists will have a little first-hand information on the quality of the beverages to be consumed after the prohibition law goes into effect in this State, a number of 'wines' and other non-alcoholic drinks, invented by the local chemists, will be served to the visiting scientists at a dinner to be given in their honor at the Hotel Washington on Thursday evening. The sub-committee, Charles A. Newhall and Professor Benson, thought this would be a good opportunity to ascertain from the members of their own profession whether the new concoctions have any 'pep.'"

After completion of the Seattle meeting, the program provided an excursion to Mount Rainier National Park, a visit to Portland, Ore., with luncheon and excursion on the Columbia River, the party being the guests of the Oregon Section, and finally at San Francisco, an entertainment by the California Section at a smoker at Techau Tavern. Dr. Franklin and Dr. Duschak had come from San Francisco, to welcome the society to California.

* * *

The Industrial Resources and Opportunities of the Northwest

An Address Made at the Seattle Meeting of the American Chemical Society

BY H. K. BENSON

In an address* upon a similar topic dealing with the Southern States, our mutual friend and co-worker, A. D. Little, expressed his temerity for a visitor to enumerate the potentialities of the South. For an entirely different reason the speaker faces a similar temerity. Inasmuch as he must remain in the locality after the attendants of the convention have departed, he must stay with the facts and representations here made. If, therefore, the figures are not as large and the possibilities not as boundless as those to which you became accustomed at the New Orleans meeting, your disappointment must be attributed to the fear, and not to the enthusiasm, of the speaker. In the brief compass of this address it is hoped, however, to call attention to the great store of natural resources and latent opportunities for development which constitute the heritage of those who labor in the Pacific Northwest.

The industrial aspect of the Northwest has been toward the East. From thence flowed the great streams of capital which have furrowed the conti-

*This journal, May, 1915, p. 281.

nental barriers and spread a network of transportation to every storehouse of natural treasures; or locked in mountain fastnesses have generated the power with which the wheels of industry may be driven. The time is coming and is now here when we may well turn from the broader phases of external development to a more minute and critical inspection of the resources about us on every hand and utilize them in the greater intensification of industry and commerce.

The Pacific Northwest constitutes an industrial unit which comprises the States of Oregon, Idaho and Washington, the province of British Columbia in Canada, and the territory of Alaska. Although composed of different political parts, whereby the natural course of industry may be hindered or benefited, yet the ultimate outlet for commodities is largely confined to the cities touching the waters of the Pacific Ocean. Material development of any portion of this area is felt throughout all of it. While it would be of great interest to comprehensively discuss the potentialities of the Pacific Northwest as a whole, the lack of published data would make it necessary to collect and compile at first hand much of this information. Time does not permit of such an extended investigation of this at present, and it is proposed therefore to present in some detail the resources of the State of Washington as a typical example of what may be found in varying degrees throughout the entire Pacific Northwest.

The total area of the Pacific Northwest includes nearly a million and a quarter square miles distributed as follows:

Oregon	96,607	sq. mi.
Washington	69,180	" "
Idaho	83,888	" "
British Columbia	395,500	" "
Alaska	586,400	" "
	1,234,575	sq. mi.

Harney County alone, in Oregon, contains as much tillable land as the State of Maryland, while the area of Alaska is greater than that of Norway, Sweden, Finland, England, Scotland and Ireland taken together. While a large portion of Alaska is mountainous, less than 1 per cent of its area consists of permanent snow fields, and its agricultural valleys contains as much tillable land as is cultivated in the States of New York, Pennsylvania and Ohio.

LUMBER INDUSTRY

We call Washington the "Evergreen" State, because its hills and mountains are enveloped with forests of fir, cedar, spruce and hemlock. With the pines of Oregon and Idaho, these forest species represent the greatest resource of the Pacific Northwest. In the States of Oregon, Washington and Idaho there are still uncut more than 50,000,000 acres of merchantable timber, from which it is estimated that over 850,000,000,000 ft., board measure, of lumber may be cut. This is more than one-third of the standing timber of the United States. The annual cut of lumber in the two States of Oregon and Washington is slightly in excess of 5,000,000,000 ft. in lumber and 8,500,000,000 shingles. Over 2000 wood manufacturing establishments, employing about 65,000 men are required in the production of the lumber and timber products of Oregon and Washington annually. The value of the timber product annually manufactured exceeds $80,000,000, of which 80 per cent is paid out for wages, taxes, rent and other production costs. When there is added to these forest areas, the 180,000,000 acres of forest lands in British Columbia with its annual cut of 1 1/3 billion ft. and an estimated stand of merchantable timber amounting to 130,000,000,000 ft. and the more or less indefinite content 20,000,000 acres of merchantable timber in Alaska, it becomes apparent that the timber products of the Northwest will continue for many years as an asset of great importance.

FERTILIZER INDUSTRY

The fertilizer resources of the Pacific Northwest are almost of equal importance as its forest products. From the waters of Puget Sound and the North Pacific the annual harvest of fisheries products exceeds $53,000,000. In 1913 the fisheries products of British Columbia were almost one-half of the total production of the Dominion, amounting to $14,500,000, and twice the value of those of Nova Scotia. The salmon industry of Alaska now extends from Ketichan in Southeastern Alaska for a distance of 2000 miles to beyond Bristol Bay in Bering Sea. In 1913 the seventy-nine salmon canneries of Alaska represented an invested capital of $31,341,670, and the annual catch of halibut, codfish, herring and whales requires an additional investment of over $6,000,000.

From the annual packing of 8,000,000 cases of salmon on the Pacific Coast results an annual production of 140,210 tons of cannery waste, which might be augmented considerably by the non-edible fish which are rejected and never reach the cannery. This waste contains in the fresh condition 10 per cent oil, 3.5 per cent bone phosphate, 1.5 per cent phosphoric acid and 3 per cent nitrogen. Of the total waste in 1913, only 16,300 tons were utilized on the Pacific Coast of the United States. From this waste were obtained 1630 tons of dry scrap and 293,000 gal. of oil. More complete utilization would increase the possible output of fertilizer and oil by tenfold.

Floating upon these same waters are the great beds of the giant kelps or seaweeds. These have been mapped by the United States Bureau of Soils, and according to this survey they yield annually over 20,000,000 tons of kelp equivalent to 750,000 tons of potassium chloride. The total imports of potash salts of all kinds in normal time is equivalent to about 400,000 tons annually. From the kelps of the North Pacific waters may be extracted not only the potash salts for domestic consumption but a surplus as well, which eventually may enable this country to export potash salts to other countries.

Until the discovery of the rock phosphate deposits of the Northwest the only commercial quantities that were known to exist in the United States were found in Florida and Tennessee. The phosphate deposits of Idaho are thirty times greater than the other known deposits of the United States. In the areas thus far surveyed by the United States Geological Survey it is estimated that over 2,500,000,000 tons of phosphate rock with 35 to 37 per cent phosphoric acid (P_2O_5) may be found.

In the ultimate utilization of cannery waste and of non-edible fish, of the potash in kelps and of phosphate rock, the Pacific Northwest offers a most promising field for the upbuilding of a great fertilizer industry.

COAL AND OIL

In the past the industrial welfare of a community was dependent upon its nearness to a coal deposit, but in the Northwest coal has competitors in the great quantities of oil from California and the electrical power of the mountain streams of the Northwest. The annual production of coal in the State of Washington is nearly 4,000,000 tons, while that of British Columbia is 2,500,000 tons. The total supply of coal in

the Pacific Coast States is estimated by Campbell and Parker at 22,000,000,000 tons, of which 20,000,000,000 are located in the State of Washington. The coal fields of Alaska cover 12,667 square miles. The estimate of the Geological survey places minimum coal resources of Alaska at 150,000,000,000 tons, which are far in excess of the original coal supply of Pennsylvania. Unlike the latter, however, much of this coal consists of lignites, the utilization of which calls for new methods and processes. Even in the State of Washington and adjacent to the coal fields themselves fuel oil is transported from California displacing annually a quantity of coal greater than that consumed.

WATER POWER

The water power resources of the Pacific Northwest constitute an important factor in power productions. The estimated developed water power of the Pacific Northwest exclusive of Alaska, exceeds 650,000 hp. The estimated undeveloped power of the Columbia River Basin is approximately 20,000,000 hp. or one-third of all the undeveloped water power in the United States, and equivalent to all the water power found in the twenty-six States east of the Mississippi River. Within economical transmission of our larger cities on tide water may be generated at least one-fifth of the available water power of the United States, exclusive of Alaska. The water power resources of the latter are said to exceed those of the Pacific Coast States.

MINERAL INDUSTRY

Much has been written of the mineral industry of Alaska and the Northwest, and it would become tedious to particularize concerning its extent and importance. The annual production of gold and silver in normal times is approximately $35,000,000. For the year 1913 the production of copper was valued at $11,300,000, of lead at $15,600,000, and of zinc at $2,500,000. The development of deposits of minor minerals has not been extensive, due to their remoteness from suitable smelting facilities. On the Seward Peninsula is a tin-bearing district of 450 square miles. Alaska has produced since 1902 over 560 tons of tin. Antimony ores are found in Alaska and Washington, molybdenum in British Colombia and Washington, tungsten in Alaska and Washington, while platinum is found in the sluice boxes of many of the placer camps of Alaska. Arsenic ores abound in the Monte Cristo district of Washington, and are smelted with the recovery of white arsenic at the Tacoma smelter.

Graphite, gypsum and barytes exist in commercial quantities in Alaska. In Washington and adjoining portions of British Columbia occur the only large deposits of limestone located on deep water along the entire Pacific Coast of the United States and Canada. Extension deposits occur in the northern tier of countries from Puget Sound to the Idaho boundary. These deposits constitute the sources for six Portland cement, one hydrated lime and numerous lime kiln plants now located within the State of Washington.

Clay deposits suitable for use in common brick manufacture are widely distributed throughout the Pacific Northwest, as are also those adapted to the manufacture of drain tile. In numerous places are also found deposits of clays which can be used for the manufacture of paving brick, sewer tile, terra cotta and firebrick. Both Washington and British Columbia are now producers of refractory brick of a high grade. Washington now ranks fifteenth in the production of clay products in the United States, forty-five firms being engaged in the industry and producing wares valued at over $2,000,000 annually.

Deposits of diatomaceous earth of superior quality have been investigated in five locations within the State of Washington. Apparently enormous quantities of this material exist in this State. Deposits of magnesium carbonate and other magnesium salts have been reported, but are not utilized. Among other raw materials available in the Pacific Northwest are iron ores suitable for mineral paints and perhaps for pig iron; talc for use as a filter in paper manufacture; silica for glass, and sand, lime, brick and large deposits of stone for structural purposes. Among the latter especial mention should be made of the Alaskan marble and of the granites and sandstones of Washington. At least three extension deposits of tufa rocks occur in Oregon and Washington.

THE OPPORTUNITIES OF THE PACIFIC NORTHWEST

The opportunities of the Pacific Northwest are to be found in the utilization and distribution of the resources heretofore recited. Less than 100,000 persons are now employed in manufacturing industries, which produce products valued at $400,000,000 in the States of Oregon and Washington. An inspection of the foodstuffs of the city of Seattle reveals what is typical of the entire Northwest. In this city of 300,000 population, during the past year 7207 cars of vegetables and fruit were shipped into the city. This is equivalent to a carload for every seven families. Of three million packages making up the total receipt, a million and a quarter came from outside the State of Washington.

Agriculture is a dormant, undeveloped industry. Less than 10 per cent of the agricultural land of Washington has been improved and is utilized for agriculture. More than 2,500,000 acres of logged-off land of agricultural character remain uncleared and idle. This is due chiefly to the high cost of clearing the land by the methods which are commonly in use. The farms which have been developed from the wilderness of débris left by the logger represent a monument of industry to those who have reclaimed them and made them factors of production. In eastern Washington the problem has been different. Instead of the jungle the desert must be overcome. Irrigation has transformed large areas into orchards and meadows of great beauty and wonderful productiveness. But even there, out of 2,000,000 acres of irrigable land not more than 25 per cent has thus far been reclaimed. In British Columbia the estimated acreage of tillable land is 253,000,000 acres, of which not more than 12 per cent is occupied, and only about one-fifth of that is under cultivation. The great need of the Pacific Northwest is settlement by colonists. Transportation is available, water and power are abundant, natural resources of unknown extent and character await development—in brief, the harvest is great, but the workers are few.

In the industries already established greater intensification and closer utilization are urgent. Fully as much timber as is manufactured into lumber is either wasted by burning or used in an uneconomic manner. As will be shown in papers presented before the convention, the fir slabs of the sawmills contain nearly as much tannin as the chestnut wood, which is the basis of the tannin extract industry of the United States. But no extract plant exists in the Northwest, and even tanneries have had hard struggles for existence in spite of the fact that great quantities of hides are readily available. Men have looked at our great forests and have seen nothing but lumber in them, and, following the line of least resistance, they have cut down these forests and manufactured a single product. In the fisheries industry the results have been largely similar. Mr. John N. Cobb,

editor of the *Pacific Fisherman*, calls attention to the neglected fishery resources of the Pacific Coast in an admirable paper presented before the first annual meeting of the Pacific Fisheries Society. In the 120,000 tons of salmon offal annually wasted are millions of pounds of salmon eggs. Siberia in 1913 prepared 500,000 lb. of salmon eggs as caviar, while 24,000 lb. were prepared upon the Pacific Coast of America in the same time. In Japan whale meat is of considerable economic importance as a food product. The whaling stations of the Pacific Coast ship certain portions to Japan, but by far the largest portion is either made into fertilizer or else wasted. Methods of processing whale meat so that it could be marketed as a food product should be worked out by the technical men of the fisheries industry whereby millions of pounds of meat might be added to our national supply annually.

These are random instances of the wasteful methods whereby our natural resources are being developed. A more complete study of existing conditions would simply tend to multiply the number of them. The Pacific Northwest needs to apply the methods of self-examination which have been so successfully applied to the industries and resources of the more congested sections of this and other countries. It needs a closer alignment with the technical thought and progress of the day. In a word, it needs, not capital, but captains of industry. With more care for the utility of natural resources and with the co-operation of the technical skill of the day, opportunities will spring from hidden places, and industries will multiply, and the Pacific Northwest will take its place in the moving streams of commerce and trade.

* * *

The following list comprises the names of those members which registered during the first day of the meeting, but it is not a complete list of the attendance:

W. H. Adolph, Tsinan, China; F. C. Atkinson, Indianapolis, Ind.; Edward Bartow, Urbana, Ill.; Stuart J. Bates, Pasadena, Cal.; J. H. Beal, Urbana, Ill.; R. C. Benner, Fremont, Ohio; J. E. Berkheimer, Tacoma, Wash.; Page R. Boyles, Salem, Ore.; C. M. Brewster, Pullman, Wash.; H. A. Bright, Washington, D. C.; C. A. Browne, New York City; H. W. Brubaker, Manhattan, Kan.; T. J. Bryan, Oak Park, Ill.; Miss M. G. Buckhous, Missoula, Mont.; G. H. Burrows, Burlington, Vt.; J. C. Butcher, Clackamas, Ore.; C. E. Coates, Baton Rouge, La.; Lillian Cohen, Minneapolis, Minn.; H. T. Corbett, Washington, D. C.; J. E. Darrah, Champaign, Ill.; J. A. Dawson, Vancouver, B. C., Canada; L. H. Duschak, San Francisco, Cal.; R. A. Dutcher, Corvallis, Ore.; R. C. Eccles, Brooklyn, N. Y.; John B. Ekeley, Boulder, Colo.; F. R. Eldred, Indianapolis, Ind.; H. C. Enders, New York City; Harry L. Fisher, New York City; Roy Fitch, Washington, D. C. Fred Flanders, Boston, Mass.; Frans Franken, Chicago, Ill.; George B. Frankforter, Minneapolis, Minn.; Edw. C. Franklin, Palo Alto, Cal.; John Fulton, Corvallis, Ore.; A. N. Gadsby, Washington, D. C.; E. D. Goldsmith, Tacoma, Wash.; George Grindrod, Kent, Wash.; W. J. Hale, Ann Arbor, Mich.; E. D. Heinrich, Tacoma, Wash.; Charles H. Herty, Chapel Hill, N. C.; E. Hockett, Columbus, Ohio; W. B. Holmes, Fremont, Ohio; J. S. Jones, Moscow, Idaho; James Kendall, New York City; J. R. M. Klotz, New York City; W. A. Lenenberger, Tacoma, Wash.; W. L. Lewis, Evanston, Ill.; J. K. Long, Evanston, Ill.; S. K. Loy, Laramie, Wyo.; Paul S. MacMichael, Auburn, Wash.; R. S. McBride, Washington, D. C.; J. F. McGregory, Hamilton, N. Y.; D. McIntosh, Vancouver, B. C., Canada; E. J. Mead, Everett, Wash; R. B. Moore, Denver, Colo.; Rokuro Nakaseko, Kyoto, Japan; Arthur C. Neish, New York City; W. A. Noyes, Urbana, Ill.; F. A. Olmsted, Oregon City, Ore.; J. C. Olsen, New York City; C. L. Parsons, Washington, D. C.; I. K. Phelps, Washington D. C.; R. W. Rea, Portland, Ore.; E. Emmet Reid, Baltimore, Md.; Clifford Richardsen, New York City; W. D. Richardson, Chicago, Ill.; E. F. Roeber, New York City; C. F. Rudmann, Ironton, Ohio; Edward Schramm, Washington, D. C.; E. Schwerdtfeger, Seattle, Wash.; R. D. Smith, Hamilton, N. Y.; O. F. Stafford, Eugene, Ore.; Frank Sternberg, Victoria, B. C., Canada; J. K. Takenaka, Portland, Ore.; Herman V. Tartor, Corvallis, Ore.; A. D. Thorburn, Indianapolis, Ind.; Bailey Tremper, Auburn, Wash.; Paul Van Horst, Tacoma, Wash.; Carl L. von Ende, Moscow, Idaho; R. G. Waltenburg, Washington, D. C.; B. L. Wehmhoff, Bremerton, Wash.; F. A. Wertz, Washington, D. C.; A. S. Wheeler, Chapel Hill, N. C.; H. H. Whiteside, Auburn, Wash.; A. M. Williamson, Niagara Falls, N. Y.; James R. Withrow, Columbus, Ohio; Frank Wright, Kent, Wash.; F. N. Yuill, Indianapolis, Ind.; Clarence Zischkan, Tacoma, Wash.; H. F. Zoller, Tacoma, Wash.

Oxy-benzyl-methyl-englycol-anhydride or "modern magic" is the title of a booklet issued by the General Bakelite Co. for distribution at the San Francisco Exposition. This booklet describes the various uses of Bakelite.

The Improvement of High Boiling Petroleum Oils, and the Manufacture of Gasoline as a By-Product Therefrom, by the Action of Aluminium Chloride[1]

BY A. M. McAFEE

The conversion of high boiling petroleum oils into lower boiling oils of greater commercial value is an old problem, and many solutions of it have been proposed. Formerly, when kerosene was worth more than gasoline, naturally the effort was to increase the yield of kerosene from crude oil; nowadays, gasoline is worth more than kerosene, and naturally the effort is to increase the yield of gasoline. But in principle, gasoline making and kerosene making from high boiling petroleum oils are the same, and most of the proposed methods make both products. With very little variation, most of them will make gas equally well. A careful examination of these methods will show, in nearly all cases, the same principle, namely, what is called cracking—heating to a sufficient temperature to cause the high boiling oils to become unstable and break down into lower boiling oils. If the heat be intense enough and the time be long enough the product will be gas; a less heat and a shorter time will make gasoline, and a still less heat and shorter time will make kerosene.

Cracking Methods

The inventors have rung the permutations on this simple idea; they heat under pressure and they heat under vacuum; they heat in the presence of gases; they heat in the presence of catalysts; they heat in tubes and they heat in boilers, etc., etc. It is safe to say that in 99 per cent of the methods which have been proposed for converting high boiling oils into lower boiling oils, "cracking" by heat is involved. Sometimes it is disguised in ornate language; sometimes it lurks behind intricate apparatus, but it is always there.

The difficulty, however, with all these cracking methods is a difficulty in principle. In breaking down the complex, high boiling hydrocarbons into several simpler ones, there is not enough hydrogen to saturate these newly formed bodies, and unsaturated hydrocarbons must necessarily result unless hydrogen be added or carbon subtracted. Hydrogen is too expensive and difficult to add, and, though a part of the carbon is readily enough subtracted and deposited, this subtraction and deposition never goes far enough, although the stillman might not be readily convinced of this. These cracked products are in large part unsaturated, and they are not desirable commercially. They are foul smelling; they are yellow in color and become rapidly more yellow on standing; they deposit large amounts of carbon on ignition in a gas engine; they burn with a smoky flame; they contain resinous bodies which cause gumming in use or on standing, etc., etc. They can, of course, be refined somewhat with sulphuric acid, but there must be too much of the acid used and too much of the oil is lost to permit in practice any thorough treatment with acid.

Aside from the poor quality of the liquid products obtained, the operation of the cracking process is attended with great difficulty where uniform results are desired. There are many variables on which the obtaining of such results depends—temperature, time, pressure and catalytic action of the walls of the containing vessel. A change in either of these variables makes a change in the products obtained. Using the same appa-

---

[1]A paper read before the Seventh Semi-Annual Meeting of the American Institute of Chemical Engineers, San Francisco, Cal., Aug. 25, 1915.

ratus, the same pressure, and consuming the same time, a difference of a comparatively few degrees of temperature in cracking operations makes marked differences in the yield and quality of liquid products.

In most of the cracking processes, pressure is employed. Sixty to 100 lb. is usual, and some have proposed much higher pressures. It is here that the greatest difficulty becomes manifest—the great danger to the operators and to the plant. There is always a deposition of hard (and flinty hard) coke on the inner walls of the heating element. Some who have had considerable experience in cracking oils have said that the coke is forced into combination with the iron making it brittle, and thus utterly unable to withstand the high temperature and pressure employed. At any rate, the deposition of the carbon occurs where the element is hottest, causing a local overheating at that point. Under such conditions the tensile strength of the steel becomes an unknown quantity—as likely as not it yields to the stress without any warning. Oil vapors of a temperature around 650 deg. Fahr. ignite spontaneously when they evolve from a still into the surrounding atmosphere. In cracking processes the temperature is 750 deg. to 850 deg. Fahr., and even higher, hence the manifest danger of cracking petroleum oils under such pressures.

Aluminium Chloride Process

When I took up the gasoline problem, some two and one-half years ago, I dismissed from consideration the idea of cracking oils. Up to this time, or since the Friedel and Crafts British patent, No. 4769 of 1877, there had been some degree of mild interest shown as regards the effect which aluminium chloride might have on petroleum oils, but no positive results had followed from this interest. It appeared to me that this reaction might have far more significance than was then apparent; I trust this paper may in a measure exemplify its significance.

I have found that with proper control of the vapors leaving the distilling system and entering the final condenser, and with sufficient time given the aluminium chloride, high boiling oils can be completely broken down into lower boiling oils, and no matter how unsaturated the high boiling hydrocarbons may be, the low boiling oils produced therefrom are sweet smelling, water white and saturated. The reaction gives little gas and only about the right amount of carbon to allow production of saturated products. The carbon is deposited not in the form of a hard baked-on carbon, but as a granular, coky mass, easily removed from the still.

But there are other products than gasoline that can be made from petroleum which are commercially worth while, although in our efforts to increase the supply of gasoline we have apparently forgotten this fact. If the market value of the various products which can be obtained from crude petroleum be plotted, it will be found that there is a peak at the low boiling end and another at the high boiling end. Gasoline is worth more than kerosene and kerosene is worth more than gas oil, while the products following gas oil, paraffin and lubricating oils are worth as much or more than the gasoline.

The problem before me, therefore, knowing the reactive power of aluminium chloride, was to apply it to crude petroleum so that good heavy oils could be obtained while at the same time converting the less valuable portions of the crude into gasoline. The solution of this problem is found in my patent.

In the practical operation of this process, crude petroleum of any kind is first distilled until the naturally occurring gasoline and kerosene, if there be any present, is distilled off. As you are probably aware, in many of our crude oils, and especially some of those from Texas, California and Mexico, there is substantially no gasoline present, and very little kerosene. But in any event, the crude is first heated to free it of any moisture which it may contain, since the oil must be perfectly dry before adding the aluminium chloride.

The next step is to add anhydrous aluminium chloride to the remaining residual oil, and then bring the mixture to boiling in the still. Boiling is usually around 500 deg. Fahr., and generally remains between 500 and 550 deg. Fahr. during the entire distillation, extending over a period of twenty-four to forty-eight hours. There is no need of employing extra pressure or vacuum or special apparatus; any still with a stirrer in it suffices.

Granted sufficient time for the aluminium chloride to get in its work, the success or failure of this process depends upon the proper control of the temperature at which the oil vapors are allowed to leave the distilling system to enter the final condenser. Between the still and the final condenser are placed two air-cooled condensers connected in series, which separate the low boiling oils from the high boiling oils, returning the latter together with any volatilized aluminium chloride to the still. For a 1000-bbl. still the air condensers which we are now using are drums of oval cross-section, 3 ft. x 6 ft. x 6 ft. high. In addition to the air condensers, a 3-ft. dome is attached to the top of the still which serves to return most of the volatilized aluminium chloride and its compounds. The operation is so controlled that the vapor is kept at the desired temperature, as indicated by a thermometer placed in the vapor line at the point of exit of vapor into the final or water-cooled condenser. The temperature at this point should not exceed 350 deg. Fahr., otherwise not only will heavy oils distil over, but the aluminium chloride (or its compounds with hydrocarbons) will enter the condenser and clog it up. Under the first named condition, the distillate obtained will be a mixture of gasoline, solvent oil and kerosene, which are afterward separated by fractional distillation. There products are all water white, sweet smelling, saturated and need no refining with sulphuric acid. In practice, no treatment is given them, except a washing with alkali, followed with water, to remove hydrogen sulphide. With proper back-trapping of high boiling oils into the still from the air-cooled condensers, and a temperature of 300 deg. Fahr. in the vapor line, the distillate obtained will be gasoline alone, which is ready for the market when washed with an alkaline solution.

I have spoken of the time which should be given the aluminium chloride for the accomplishment of the desired results. It is a mistake to assume that with a given amount of aluminium chloride and boiling it up with oil the desired results will be obtained. That is far from the truth. I do not wish to impose upon your patience by dismissing consideration of the mechanism of this reaction by simply saying it is catalytic. I am fairly well satisfied that it is one of association or combination in the liquid phase and dissociation in the vapor phase. It is well known that aluminium chloride exists in the solid and liquid states as Al_2Cl_6 and in the vapor state as $AlCl_3$. It is also well known with what avidity aluminium chloride in the solid or liquid state will combine with other salts to form double salts. The most common of these double salts is that of aluminium and sodium chloride, which, at one time, as you know, was the source of metallic aluminium (Castner process). Aluminium chloride probably combines with these high boiling complex hydrocarbons in much the same way as it combines with sodium chloride, and when the boiling temperature is reached these double com-

pounds become unstable, and dissociate into lower boiling hydrocarbons, which, under the temperature control imposed in the vapor line, leave the distilling system as fast as produced. Al_2Cl_6 is again formed, and is capable of combining further with other high boiling hydrocarbons remaining in the still, and free carbon is formed simultaneously. This view of the reaction here involved is confirmed, I believe, by the operating conditions mentioned heretofore as necessary for obtaining the desired results.

While the operation, using crude oil as the starting material, can be carried on to produce larger or smaller quantities of gasoline, in practice it is carried on so as to convert the gas oil fraction into low boiling hydrocarbons and leave most of the high boiling hydrocarbons, that is, the paraffins and lubricating oils. Accordingly, the operation is interrupted after a portion of the crude has been converted into low boiling products, and the high boiling oil remaining in the still is pumped off while hot and on cooling is worked up into the usual paraffin and lubricating products. The aluminium chloride remains in the still enmeshed in a mass of coke, and the methods of its recovery are found in my patents, which, if I may, I will refer to further on in this paper.

Results of Tests

As illustrative of the action of aluminium chloride on high boiling petroleum oils I shall give below results obtained on typical crudes. For the sake of convenience, the distillate obtained by distilling the crude before the addition of aluminium chloride will be termed "primary distillate," the oil remaining in the still being termed "primary residual oil"; the distillate obtained by distilling the primary residual oil with aluminium chloride will be termed "secondary distillate," and the oil remaining in the still "secondary residual oil." Fahrenheit temperature and Baumé gravity are used throughout. The distillation tests were made on 100 c.c. samples contained in standard Engler flasks connected to a 22-in. Liebig condenser. All flash points noted are in open cut tester. Viscosities noted are on the Saybolt universal viscosimeter at 100 deg. Fahr. W.W. and S.W. are abbreviations for water white and standard white respectively.

Texas crude of 20.8 gravity was distilled until free from moisture and until the naturally occurring gasoline and kerosene had been distilled over.

Yield	Per Cent Crude
Primary distillate	7.14
Primary residual oil	91.26
Loss	1.60
Total	100.00

Tests on Primary Distillate.

Gravity	36
Bromine No.	5.46

Distillation Over, Per Cent	260 Deg. F.
10	320
20	344
30	368
40	386
50	400
60	442
70	468
80	490
90	505
95	520

The primary distillate yielded on fractional distillation the following products:

	Per Cent Crude	Grav.	Color	Per Cent Sulphur	Bromine Number
Gasoline	0.303	58.0	W.W.	0.065	4.8
Gas naphtha	0.180	51.0	S.W.	0.103	3.1
W. W. kerosene	1.260	41.6	W.W.	0.071	..
S. W. kerosene	1.530	40.9	W.W.	0.133	..
Gas oil	3.791	31.2	.....	0.386	..
Loss	0.076	....	.....	.....	..
Total	7.140				

Tests on Primary Residual Oil

Gravity	19.8
Viscosity	302

Distillation Over, Per Cent	480 Deg. F.
10	530
20	566
30	600
40	656
50	680

To the primary residual oil was added 7½ per cent by weight of anhydrous aluminium chloride, and the mixture brought to boiling. The following observations were made during the course of the run:

Time, P. M.	Temperature of Still	Temperature of Vapor Line	Distillate, Per Cent Charge	Grav.	Distillation Test: Over Deg. F.	Per Cent Below 350 Deg. F.	Per Cent Below 450 Deg. F.	Dry Point
1.00	454	268	Showed up	...	...	..	..	...
1.30	479	290	2.86	55.9	110	68	80	490
1.45	488	300	2.86	55.2	110	69	84	490
2.15	495	302	2.86	54.4	110	66	80	490
2.45	504	290	2.86	54.1	110	66	81	490
3.15	508	290	2.86	53.5	110	65	80	490
4.15	518	340	2.86	53.7	110	65	80	490
4.45	523	340	2.86	53.7	110	65	83	490
6.00	525	340	2.86	53.5	105	60	82	490
7.00	530	344	2.86	53.3	100	58	81	490
8.30	530	340	2.86	53.5	100	58	81	490
10.30	542	340	2.86	53.2	100	60	83	490
A. M.								
1.00	547	320	2.86	52.6	100	60	83	490
4.00	547	300	2.86	52.4	100	60	83	490
6.30	552	290	2.86	52.8	100	58	83	495
10.00	551	305	2.86	50.6	100	58	83	500
P. M.								
1.00	557	302	8.57	49.7	100	55	85	510
	From back trap		1.39					

The operation was stopped at the end of twenty-four hours.

Yield	Per Cent Charge	Per Cent Crude
Secondary distillate	52.86	48.24
Secondary residual oil	31.14	28.42
Loss (gas and coke)	16.00	14.60
Total	100.00	91.26

Tests on Secondary Distillate

Gravity	51.1

Distillation Over, Per Cent	100 Deg. F.
10	174
20	228
30	265
40	294
50	324
60	357
70	388
80	428
90	475
95	500

The secondary distillate on fractional distillation yielded the following products:

	Per Cent Charge	Per Cent Crude
Gasoline	36.18	17.45
Gas naphtha	26.62	12.85
W. W. kerosene	2.65	1.28
S. W. kerosene	9.53	4.59
Solar oil	21.80	10.52
Loss	3.22	1.55
Total	100.00	48.24

The tests on the gasoline and the gas naphtha are as follows:

	Gasoline	Gas Naphtha
Color	W.W.	S.W.
Odor	Sweet	Sweet
Bromine No.	4.2	3.2
Dr. test	O.K.	O.K.
Heat test	4	3
Sulphur	0.056 %	0.054 %
Gravity	64.5	50.2

Distillation Over, Per Cent	117 Deg. F.	Gravity	215 Deg. F.	Gravity
10	160	82.1	240	57.0
20	170	79.0	246	55.0
30	179	75.3	253	54.1
40	190	70.9	260	52.8
50	208	66.0	270	51.3
60	222	61.8	280	50.2
70	239	57.7	293	49.1
80	261	64.2	306	47.5
90	293	50.4	332	45.4
98 Dry Point	339	....	350	....

The secondary residual oil obtained in the above process had the following tests, when freed of aluminium chloride:

Color	Red—green bloom
Flash	185 deg. F.
Fire	250
Viscosity	105

This residual oil was reduced with steam in order to make lubricating oil.

Yield	Per Cent Charge	Per Cent Crude
Gas oil	10.00	2.84
Lubricating oil	90.00	25.58
Total	100.00	28.42

Tests on Lubricating Oil

Color	Red—green bloom
Gravity	21.9
Flash	290
Viscosity	122

Summary of Yield of Products from Texas Crude by the Aluminium Chloride Process

	Per Cent Crude
Primary gasoline	0.30
Secondary gasoline	17.45
Primary gas naphtha	0.18
Secondary gas naphtha	12.85
Primary kerosenes	2.79
Secondary kerosenes	5.87
Gas oil	17.15
Lubricating oil	25.58
Total	82.17
Loss account distilling primary distillate	1.60
Loss account distilling with aluminium chloride	14.60
Loss account redistillation of primary distillate	0.08
Loss account redistillation of secondary distillate	1.55
Total	100.00

The following table compares the yield of products from Texas crude by the aluminium chloride process with the yield of products as obtained when the crude is distilled in the usual manner:

	Per Cent Crude, Aluminium Chloride Process	Per Cent Crude, Usual Process
Gasoline	17.75	Zero
Gas naphtha	13.03	0.10
Kerosenes	8.66	4.30
Gas oil	17.15	52.00
Lubricating oils	25.58	25.50
Asphaltic residual oil	....	12.00
Total	82.17	93.90
Loss	17.83	6.10
Total	100.00	100.00

In ordinary practice no gasoline is obtained from this type of Texas crude; by the aluminium chloride process 17.75 per cent is obtained and those who are familiar with the tests on petroleum products will see that this gasoline is as good as the natural gasoline made from any crude petroleum. The gas naphtha, which might very well be mixed with the gasoline, has been increased from 0.1 per cent to 13.03 per cent. It will be observed that these low boiling oils have been made at the expense of the gas oil fraction and the asphaltic residual oil, the latter being broken down completely. Gas oil is the least valuable constituent of the crude. The asphaltic residual oil is used for fuel or is made into asphalt. The yield of lubricating oil by the aluminium chloride process is about the same as that in the usual process, but the quality of the former is greatly improved by virture of the saturating effect of the aluminium chloride and the elimination of asphaltic and resinous constituents from the oil. I have samples here of these products that I shall be glad for any of you to examine.

It will not be necessary to go into so much detail with the remaining crudes of which I desire to speak, but I have wanted to give you these figures on Texas crude to show how regularly the reaction proceeds over a long period of time, what the physical characteristics of the products are, and the yield as compared with the usual process.

A Caddo (Louisiana) crude of 41 gravity was distilled to free it from moisture and natural gasoline:

Yield	Per Cent Crude
Primary distillate	26.19
Primary residual oil	71.43
Loss	2.38
Total	100.00

Tests on Primary Distillate

Gravity	58.2
Distillation Over, Per Cent,	160 Deg. F.
10	215
20	232
30	247
40	260
50	276
60	296
70	315
80	343
90	402
95	450
Dry point	500

The primary distillate on fractional distillation yielded:

Yield	Per Cent Charge	Per Cent Crude
Gasoline	82.00	21.48
Kerosene	15.00	3.93
Loss	3.00	0.78
Total	100.00	26.19

Five per cent by weight of aluminium chloride was added to the primary residual oil and the mixture brought to boiling. Distillation was continued for forty-eight hours, the temperature of the vapor line at the point of exit into the final condenser being held around 350 deg. Fahr.:

Yield	Per Cent Charge	Per Cent Crude
Secondary distillate	58.33	41.67
Secondary residual oil	26.20	18.71
Loss (gas and coke)	15.47	11.05
Total	100.00	71.43

Tests on Secondary Distillate

Gravity	54.0
Distillation Over, Per Cent	102 Deg. F.
10	212
20	260
30	293
40	315
50	340
60	365
70	388
80	414
90	450
95	480
98 Dry point	500

The secondard distillate on fractional distillation yielded the following products:

Yield	Per Cent Charge	Per Cent Crude
Gasoline	50.00	20.84
Solvent oil	40.00	16.67
Gas oil	6.00	2.50
Loss	4.00	1.66
Total	100.00	41.67

Following are the tests on the gasoline and solvent oil:

Color	W.W.	W.W.
Odor	Sweet	Sweet
Bromide No.	2	3
Dr. test	O.K.	O.K.
Heat test	2	2
Gravity	58.0	48.1
Distillation Over, Per Cent	120 Deg. F.	340 Deg. F.
10	198	354
20	221	360
30	240	364
40	258	369
50	272	374
60	288	381
70	301	390
80	322	400
90	348	416
95 Dry point	362	430
98 Dry point		440

Tests on Secondary Residual Oil

Color	Red—green bloom
Gravity	36.5
Flash	260 deg. F.
Fire	300
Pour	90 deg. F.

This residual oil was distilled until 30 per cent of the charge had been distilled over.

Yield	Per Cent Charge	Per Cent Crude
Gas oil	30.00	5.61
Paraffin residual oil	70.00	13.10
Total	100.00	18.71

Tests on Paraffin Residual Oil

Color	Amber
Pour	105 deg. F.
Flash	375
Fire	420

Summary of Yield of Products from Caddo (Louisiana) Crude Oil by the Aluminium Chloride Process

	Per Cent Crude
Primary gasoline	21.48
Secondary gasoline	20.84
Secondary solvent oil	16.67
Primary kerosene	3.93
Gas oil	8.11
Paraffin residual oil	13.10
Total	84.13
Loss account aluminium chloride distillation	12.71
Loss account working distillates into standard products	3.16
Total	100.00

The following table compares the yield of products from Caddo crude by the aluminium chloride process and the yield of products as obtained in usual practice.

	Per Cent Crude Al_2Cl_6 Process	Per Cent Crude Usual Process
Gasoline	42.32	18.00
Solvent oil	16.67	12.00
Kerosene	3.93	35.00
Gas oil	8.11	21.00
Paraffin residual oil	13.10	11.00
Total	84.13	97.00
Loss	15.87	3.00
Total	100.00	100.00

This crude belongs to the same type as Pennsylvania crude—the type known as paraffin base crude. Their products are clean smelling and require but little acid in refining. But even this type of crude is considerably improved by the aluminium chloride process, while at the same time the yield of gasoline is greatly increased. The paraffin residual oil from Caddo crude is black and tarry on account of the presence of asphaltic constituents, but these are not usually present in large enough amounts to prevent the manufacture of good paraffin and paraffin lubricating oil. The distillation with aluminium chloride destroys the asphaltic constituents, giving an amber colored residual oil which may be easily worked into a product, commercially known as vaseline, or into paraffin and paraffin lubricating oils. At the same time the yield of gasoline from the crude is increased from 18 per cent to 42.32 per cent.

An Oklahoma crude of 34 gravity was distilled to free it from moisture and natural gasoline.

Yield	Per Cent Crude
Primary distillate	20.83
Primary residual oil	78.31
Loss	0.86
Total	100.00

Tests on Primary Distillate

Gravity	54.1
Color	W.W.

Distillation Over.

Per Cent	152 Deg. F.
10	210
20	226
30	242
40	252
50	271
60	290
70	313
80	345
90	408
95 dry point	455

This primary distillate on fractional distillation yielded the following:

Yield	Per Cent Charge	Per Cent Crude
Gasoline	70.00	14.58
Kerosene	20.00	4.17
Gas oil	7.50	1.56
Loss	2.50	0.52
Total	100.00	20.83

Tests on Primary Residual Oil

Color	Black
Gravity	29.8
Flash	170
Fire	205
Pour	20

Distillation Over,

Per Cent	330 Deg. F.
10	436
20	484
30	543
40	590
Below 600 deg. F.	43 per cent

To the primary residual oil was added 5 per cent by weight of aluminium chloride. Distillation was then continued for a period of 48 hours; the temperature of the vapor line at the point of exit into the final condenser being held around 350 F.

	Per Cent Charge	Per Cent Crude
Secondary distillate	64.61	50.60
Secondary residual oil	17.97	14.07
Loss	17.42	13.64
Total	100.00	78.31

Tests on Secondary distillate

Gravity	48.3

Distillation Over,

Per Cent	140 Deg. F.
10	225
20	270
30	294
40	326
50	358
60	382
70	413
80	454
90	503
95	547
98 Dry point	570

On fractional distillation this secondary distillate yielded the following:

Yield	Per Cent Charge	Per Cent Crude
Gasoline	40.00	20.24
Kerosene	50.00	25.30
Gas oil	7.50	3.80
Loss	2.50	1.26
Total	100.00	50.60

Tests on gasoline:

Color	W.W.
Odor	Sweet
Bromine No.	1.5
Dr. test	O.K.
Heat test	2
Sulphur	.027%
Gravity	64.5

Distillation Over,

Per Cent	130 Deg. F.	Gravity
10	160	83.8
20	186	76.2
30	200	70.1
40	213	66.6
50	222	62.8
60	238	60.4
70	252	58.5
80	270	56.1
90	299	53.3
Residue	8.3%	48.2

Tests on Secondary Residual Oil

Color	Red—green bloom
Gravity	28.2
Pour	90 deg. F.
Flash	230 deg. F.

This secondary residual oil was distilled to produce wax stock and cylinder oil.

Yield	Per Cent Charge	Per Cent Crude
Wax stock	60.00	8.44
Cylinder oil	40.00	5.63
Total	100.00	14.07

Summary of Yield of Products from Oklahoma Crude by the Aluminium Chloride Process

	Per Cent Crude
Primary gasoline	14.58
Secondary gasoline	20.24
Primary kerosene	4.17
Secondary kerosene	25.30
Gas oil	5.36
Residual oil	14.07
Total	83.72
Loss account aluminium chloride distillation	13.64
Loss account working distillate into standard products	2.64
Total	100.00

The following table compares the yield of products from Oklahoma crude by the aluminium chloride pro-

cess and the yield of products as obtained in usual practice.

	Per Cent Crude Aluminum Chloride Process	Per Cent Crude Usual Process
Gasoline	34.82	12.50
Kerosene	29.47	41.00
Gas oil	5.36	35.00
Residual oil	14.07	9.00
	83.72	97.50
Loss	16.28	2.50
Total	100.00	100.00

The residual oil from this crude by the usual process is a black, tarry mass, containing large amount of asphaltic constituents and also paraffin. The amount of asphaltic constituents is so great, as a rule, that it is difficult to make paraffin and paraffin lubricating oils of the same grade as that obtained from Pennsylvania or Caddo residuums. By the aluminium chloride process this residual oil is cleaned of its asphaltic constituents, and paraffin wax and paraffin lubricating oils of excellent quality are made therefrom. At the same time, the yield of gasoline from the crude is greatly increased, at the expense of the less valuable fractions of the crude.

Although the crude petroleums from the various oil producing districts in this country differ greatly in quality and in chemical composition, yet they are generally divided into three types: Asphaltic-base crude, paraffin-base crude, and paraffin-asphaltic-base crude. The oils I have spoken of in this paper are representative of each of these types; Texas, asphaltic-base crude, Caddo, paraffin-base crude, and Oklahoma, paraffin-asphaltic-base crudes. To give figures on other crudes would be merely a repetition of the results obtained on one of these. I shall therefore not take the time to give further examples. I might add that among the samples here are products made by the aluminium chloride process from 14 gravity California crude and 20 gravity Mexican crude.

Recovery of Aluminium Chloride

But all the good results of this process would be of no commercial value if the aluminium chloride could not be reclaimed. This chemical when made on the ton scale is not so expensive as it is when made on the pound scale, but nevertheless its cost is high, and from a dollars and cents point of view, it is necessary to recover it. And this is done by the processes set forth in my patents.

After a time, 48 hr. or longer, aluminium chloride used in distilling oils, even the driest of oils, loses its catalytic activity and becomes converted into a coky mass. Analysis of the coky mass shows chlorine and aluminium present in the right proportions to form aluminium chloride, but the latter is, so to speak, masked. It does not display its ordinary reaction with petroleum hydrocarbons. The granular coky residue after it comes from the oil converting process, carries varying amounts of oils with it. If allowed to cool down in the presence of the body of oil, it may carry 40 to 50 per cent of its weight of oil. If the oil body has been separated while hot from the coky residue, the amount of oil will be reduced to 4 or 5 per cent.

After removing the oil, or the bulk of it, from the coky residue, the aluminium chloride can be extracted from the latter with water or steam to obtain a concentrated solution of hydrated aluminium chloride. Aluminium chloride in the hydrated state does not have the catalytic property of the anhydrous material, but the hydrated salt can be used as the raw material for making the anhydrous salt. To do this, advantage is taken of the property of hydrated aluminium chloride breaking up when moderately heated to form aluminium oxide and hydrochloric acid gas. The alumina when mixed with carbon and treated with hydrochloric acid vapors at a high temperature, react to form the anhydrous chloride, hydrogen and oxides of carbon. In utilizing this property, one portion of the hydrated chloride is heated to produce hydrochloric acid vapors and alumina, and these vapors on drying enter a further charge of alumina and carbon heated to redness. The hydrochloric acid vapors given off at a moderate temperature are thus utilized in further operations at high temperatures.

In another method of recovery, and the preferred one, the coky residue is heated to red heat in an atmosphere of chlorine which disengages the aluminium chloride from the carbon. Aluminium chloride volatilizes normally at a temperature around 365 deg. Fahr., but the coky residue may be heated to redness without much evolution of these vapors. If the heating is done in an atmosphere of chlorine the aluminium chloride is unlocked, so to speak, and vaporizes away from the carbon, and is condensed in suitable receivers.

Of course, the last and ultimate test of any process is whether it will work, and work successfully without undue petting. That the aluminium chloride process is now an assured commercial success, is, of course, due to its own merits. But I cannot forego this opportunity to speak of the generous aid from the Gulf Refining Company, which has made success possible, and the valuable advice and help from its officers.

Although this account by no means covers the full scope of the aluminium chloride reaction with petroleum oils, yet to speak further would lead me outside of my subject.

The New Mill of the Daly West Mining Co., Park City, Utah

By L. O. Howard

The destruction by fire, in December, 1913, of the mill and shaft house of the Daly West Mining Co. at Park City, Utah, gave the company an opportunity to simplify its practice. The old plant was characterized by all the complications and repeated retreatments, a multiplicity of screens and classifiers, endless succession of middling tables, etc., that the practice of a decade ago favored in the concentration of lead and zinc ores.

The old mill was of the hillside type, and in the same structure as the shaft- and boiler-house. This resulted in the total destruction of the surface plant when fire started in a portion of the works.

The ore of the Daly West mine is a sulphide of lead and zinc, with some copper, and about 3 oz. of silver for each per cent of lead, in a gangue of limestone and quartzite. It is mined to a depth of 2100 ft. through a two-compartment shaft. First-class ore, assaying about 18 per cent lead, 9 per cent zinc, 2 per cent copper, 52 oz. of silver, and 0.04 oz. of gold, is sorted out underground, hoisted to the 1200-ft. level, and hauled 2½ miles through the Ontario drain tunnel to Park City, near the site of the old Ontario mill. Second-class ore is hoisted to the surface. For some years this ore has assayed about 5 to 6 per cent lead, 5 to 6 per cent zinc, and 7 to 8 oz. silver.

THE OLD MILL

Preceding the description of present practice and for purposes of comparison, a brief outline of previous practice may be of interest. All ore was hoisted in cars on two three-deck cages and dumped over eight grizzlies into sixteen separate coarse and fine-ore bins, from which it was taken by belt conveyor to a Gates crusher set to 1 in. From the 1.5-in. oversize of the grizzlies, waste and first-class ore was sorted out.

Second-class ore was delivered to the mill bins. After sampling it dropped to the first set of rolls, then to the limiting trommel, where all ore over three-mesh was sent to finishing rolls, then to another three-mesh trommel. The oversize of this trommel was delivered to a two-mesh scalping trommel, which returned its oversize to the finishing rolls. The undersize from both three-mesh trommels was delivered to a series of trommels having screens of four-mesh, six-mesh and eight-mesh cloth. The respective oversizes were sent to four sets of two two-compartment Harz jigs each. Concentrate was taken off the four coarse jigs through the hutches and side-draw gates. The fine jigs made only hutch product and tailing.

Coarse tailing, after dewatering, was reground in three Sherman mills, which were modifications of the Huntington mill.

Following the last trommel came the first tanks of the classification system. The old mill had no hydraulic classifiers, but used a system of tanks and classifiers devised by the mill superintendent and known as Sherman tanks and Sherman classifiers. The latter were of special interest. They were cylindrical with conical bottoms, and set in series with a progressive increase in diameter and decrease in height. Fig. 1 shows some of these tanks in the ruins of the old mill. In the main

FIG. 1—A PORTION OF THE OLD DALY WEST MILL, SHOWING ARRANGEMENT OF SHERMAN CLASSIFIERS. NEW SHAFT-HOUSE AND HEAD FRAME IN BACKGROUND

mill the diameters were 4, 6, 8, 10 and 12 ft. Pulp was fed through a central cylinder, of one half the cross-sectional area of the outside cylinder, and the overflow passed upward between the two cylinders and into a launder at the periphery of the larger cylinder. From the spigots were drawn the feeds for the various concentrating machines.

From the first tanks another set of fine jigs was fed, which made a finished hutch, the tailing joining the reground tailing from the coarse jigs. This tailing went to the next two Sherman tanks, feeding six Wilfley tables, which made four products; concentrate to smelter, tailing, slime, and middling, which was sent to three more Wilfleys, which made similar products to the first, the middling from these being passed over two more Wilfleys.

The slime from the first Wilfleys, and the overflows from the various Sherman tanks, went to a set of five Sherman classifiers. Tailing from the three sets of Wilfleys and slime from the last two sets were passed over an eight-mesh screen, the undersize going to other Sherman classifiers in a separate structure, known as Mill No. 2, the oversize going to Mill No. 3.

The five Sherman classifiers in Mill No. 1, receiving the coarser overflows from the Sherman tanks, and some returns from later parts of the system, fed three Wilfley tables and two Sherman slime tables, which were similar to the old tray-type of Wilfley table. All these tables made finished concentrate, sent tailing to Mill No. 2 and returned middling to the five classifiers. The overflow of the last of these classifiers was further settled in a long tank, which fed two more Sherman slime tables, which made a finished concentrate and sent tailing to the tailing plant, Mill No. 2.

The Old Tailing Mill

Mill No. 2 was characterized by a long-extended series of tanks and classifiers of the Sherman type. Tailing was received in a 6 x 6 tank, the spigot product from which was screened over 8-mesh, undersize being treated, after passing through another small tank, on a 2-compartment Harz jig, where a finished concentrate was made, tailing going to No. 3 Mill. Oversize of 8-mesh was reground in a Sherman mill and sent to six Sherman classifiers, along with the overflow from the tanks. These tanks varied in diameter as follows: 3 ft., 4.5 ft., 5.5 ft., 7.5 ft., 10.5 ft. and 14 ft.

This set of classifiers fed three Wilfley tables and three Overstrom tables, all of which returned middling and slime to the classifier, made finished concentrate and sent tailing to mill No. 3.

The overflow from the classifiers was further settled in eighteen 6 x 6 tanks, which fed one slime table, making finished concentrate, middling to be returned to classifiers, and tailing to Mill No. 3. The final overflow from the eighteen tanks was used as wash water on the tables in Mill 2, not without further settling, however.

Mill No. 3

Mill No. 3 was simple. Here the incoming tailing was received in a settler, the material which settled being discarded (the first discard from the plant) and the overflow again settled. The spigot of the second settling tank discharged to an eighty-mesh screen, which rejected the oversize and fed the undersize to four slime tables, which also received the overflow of the second settler, after it had been further thickened in two more tanks. These slime tables made finished concentrate and tailing and returned middling to the second settler.

At a later time there was added a trommel and two more jigs to treat further the coarse material.

The writer has given the above description with some hope, but not too much expectation, that the reader will be able to visualize the practice. At least it will serve to emphasize the complication of the old plant and serve as a measure of the simplification attained in the new plant.

According to the report of the mill superintendent for 1913, the old plant treated 190 tons per 8-hr. shift, with an extraction of 99.6 per cent of the lead, 22 per cent of the zinc and 79.55 per cent of the silver. The high lead extraction is due to the custom of figuring the lead in zinc concentrate as part of the extraction. The mill treated 59,233 tons of ore assaying 5 per cent lead, 7.7 oz. of silver and 4.3 per cent of zinc, producing 8332 tons of lead concentrate assaying 34.54 per cent lead, 40.01 ounces silver and 1598 tons of zinc concentrate assaying 35.37 per cent zinc, 4.83 per cent lead and 19.27 oz. of silver. These figures would indicate an extraction of 97 per cent of the lead. It is not stated how the weight of crude ore was determined or how the sample was taken, so that the reason for this apparently high recovery is not evident.

The mill was driven electrically, power being generated by boilers, 300 horsepower being required.

The mill force consisted of twenty men per shift.

The illustrations of the present mill—Figs. 2, 3 and 4—show that much less floor space is required, and precaution has been taken to have the shaft-house, crusher-house and mill widely separated.

The New Mill Structures

The new mill, which went into commission in January of this year is housed in two structures, one 71 ft. long, 27 ft. wide and 60 ft. high from floor line to top of ore bins, housing the storage bins and the primary crushers. The main mill building has the approximate dimensions shown in the sketch, Fig. 5. The crusher-house is of frame construction, as is the mill proper, the latter being covered with corrugated iron. The

FIG. 2—VIEW OF DALY WEST MILL, LOOKING WEST

mill is of the hillside type, the fall from the head of the mill proper to the tailing launders in the tunnel beneath the mill being about 70 feet.

There are five levels. At the top are the receiving bins. On the floor below, the fourth, are two Franz jigs, above which are the feeding trommel and Akins classifier. On the third floor are the roughing Wilfleys, Harz jigs, Sherman tanks and regrinding rolls. On the second floor are eight concentrating tables and the flotation plant, and on the first, the Harz tailing jig and concentrate launders.

The accompanying flow sheet shows the greater simplicity of the new plant. The ore is hoisted in two 4-ton skips and dumped into bins in the head-frame, waste being dumped into its own bin and trammed to the dump.

The seoond-class ore is drawn on to an 18-inch belt conveyor, 270 ft. long, which delivers the ore to the bins at the top of the ore-house, at an elevation 12 ft. lower. The ore is received in two bins, 12 ft. x 12 ft. in cross-section, and 35 ft. deep, holding 600 tons or enough for three days' run. From the bins the ore is fed by 30-in. Stephens-Adamson belt feeders, adjustable to three speeds, over 3-ft. x 6-ft. grizzlies, having a 45-deg. slope, with 2-in. spacing of the bars, which are of cast iron, 3 in. deep, ¾ in. wide at the top and ¼ in. wide at the bottom.

Magnetic Removal of Steel from Feed

A 10-in. x 20-in. Blake crusher, made by the Colorado Iron Works, takes the oversize and discharges to a trommel, which is 48 in. by 72 in., and is covered with double-crimped wire screen, having two meshes to the inch. A 24-in. belt conveyor, 12 ft. long, takes the oversize of the trommel to a 48-in. Symons disc crusher. The head pulley of this conveyor is magnetized to remove all pieces of steel from the feed.

In operating the Symons crusher there has been at intervals some trouble due to choking which has been gradually overcome. Points of steel, 6 to 8 in. long, have gone into the crusher without other effect than to blow the fuses. Since the mill was started the crusher has given generally good results, but after six months' service further trouble was had due to the discs becoming wedged with babbitt, stripping the driving gears and interfering with the operation of the mill until new parts could be obtained from the manufacturer. At the time of the writer's visit the mill was crippled from this cause, so that the best work of the newer equipment could not be seen.

The discharge of the Symons crusher and the undersize from the trommel are taken from the ore-house to the mill bins by a 24-in. Robins belt conveyor, 210 ft. long, up a 6-deg. slope. Midway of the belt travel is a Blake-Denison weigher, having a capacity of 30 tons per hour.

Franz Jig Removes the First Concentrate

The ore is sampled as it falls into the bin by a box rotating on a vertical axis at the rate of one revolution in 10 minutes. After the cut has been made the box travels a half revolution, to a point where its front end comes in contact with an inclined rail which tilts the box so that it discharges through the back end to the sample chute.

From the bin the ore is fed into a 48-in. by 72-in. trommel, covered with a two-mesh screen of double-crimped wire cloth. The oversize goes directly to one of two Franz jigs, the undersize going to the other after the slime has been removed in a 51-in, Akins classifier.

These jigs are of the movable screen type and are more often seen in the Missouri zinc districts than in the West. The screens are 10 ft. long and 27 in. wide. On the coarse jig the screen size is changed at intervals, the first two feet having 5/16-in. apertures, the next three feet having ½-in. apertures and the remainder being divided between screens having apertures of ⅝-in. and ¾-in. respectively. The fine jig has 2½ ft. each of the following sizes: 3/16-in., ¼-in., 5/16-in., ⅜-in. Screens are of plate punched with round holes. Both jigs are run at 240 revolutions per minute, the fine jig having a stroke of ¾ in. and the coarse of 1 in. to 1¼ in.

The feed is divided in the proportion of 120 tons per

FIG. 3—VIEW OF DALY WEST MILL, LOOKING EAST

day to the coarse and 80 tons to the fine. The coarse jig makes three finished hutch products averaging 30 per cent lead, which go to the lead concentrate bins. The first two hutches of the fine jig are also finished products and will average about 35 per cent lead. The third hutch of the fine jig goes to two Wilfleys, which make a finished zinc concentrate and a tailing, which is retreated on the Harz jig on the lowest level of the mill.

Rolls Used for Regrinding

The tailing from the coarse jig is reground in 14-in. x 36-in. rolls, instead of Sherman mills, as in the old plant, and is elevated to a series of two sets of three Colorado Iron Works impact screens, where three sizes are made: on four-mesh, through four-mesh on eight-mesh, and through eight-mesh. The coarse is returned to the rolls. The middle size is treated on two three-compartment Harz jigs, which make two finished hutch concentrate products, and a third hutch and tailing, which are retreated on the same Wilfleys that receive the third hutch product of the fine Franz jig.

The undersize joins the slime from the Akins classifier and from the later table treatment, and is classified in a 5-spigot Richards-Janney classifier. Each spigot

FIG. 4—DALY WEST CRUSHER HOUSE WITH CONVEYOR SHEDS. MILL ON RIGHT. ASSAY OFFICE IN LEFT CENTER FOREGROUND

feeds two Wilfley tables, the oversize, after thickening, going to the flotation plant. Contrast this simple separation of sizes with the complicated mechanism of the old plant.

Fine Concentration on Wilfley Tables

The ten Wilfleys make similar products, a finished lead, concentrate, tailing, and middling, which is retreated for a finished zinc concentrate and a tailing on three Wilfleys, and head water, which is returned to the classifier.

The concentrates from the Harz jigs and Wilfley tables drop to separate lead and zinc launders suspended on hangers and running across the width of the mill in a tunnel on the lowest level. The head end of the launders is connected to a shaking device which causes the concentrate to flow forward to two sets of two elevators in series, which discharge into two Akins dewaterers, the drained concentrates dropping into lead and zinc bins. They are then trammed in one-ton cars through a tunnel to a sub-level of the ore-house, and are then elevated on a cage to the conveyor shed connecting shaft and ore-house, and trammed to the shaft. They are then lowered to the 1200-ft. level and hauled out through the Ontario tunnel to Park City, where they are loaded on wagons and hauled to the sampling works, a short distance below the city.

All the tailing from the concentrating department goes to a two-compartment Harz jig, on the lowest level, the hutch products being returned to the circuit ahead of the impact screens.

The tailing from this jig is sampled by a tilting box sampler before running into the tail race.

Flotation Department

The feed to the flotation plant consists of slime from the Richards-Janney classifier, which is thickened in one large and 23 small settling tanks of the type used in the old mill. The unit consists of two mixing cells and fourteen flotation cells, having a capacity of thirty tons of dry slime per day. The type is similar to that used by the Federal Lead Company. Each cell is 4 ft. 4 in. long by 20 in. wide and 5 ft. 8 in. deep at the tailing discharge end. They are set side by side, with their sides in common. The illustration, Fig. 7, shows an end view, and the shape of the cells is further illustrated diagramatically in the approximate sketch, Fig. 8.

The slime is fed into the first mixing chamber, where it is mechanically agitated by a vertical propeller driven by belt from a line shaft extending the length of the unit. From this compartment it is drawn into a second similar one and then into a third, which is part of the first flotation cell. Each flotation cell has two compartments, one similar to the mixing cells and another longer one, where the flotation is effected. A flotation concentrate is taken off each cell, the tailing passing through the whole system of cells in series.

The propeller in one cell draws the tailing from the bottom of the preceding flotation compartment and discharges through a slot at the top into its own flotation comparament. The froth floats to the opposite end of the flotation compartment and is skimmed off by a

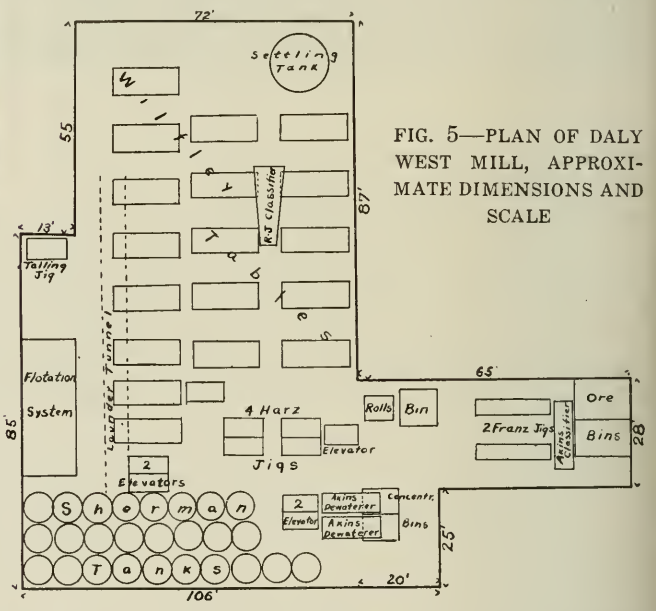


FIG. 5—PLAN OF DALY WEST MILL, APPROXIMATE DIMENSIONS AND SCALE

paddle wheel which drops it into the concentrate launder, where a jet of water breaks the froth. The concentrate flows to a centrifugal pump which lifts it to an elevator delivering to the concentrate bins. This concentrate is marketed as a lead product.

The tailing settles to the bottom edge of the flotation compartment and is drawn into the next cell and again subjected to flotation, until it has passed the final cell, when it goes to the tail race. Flotation tailing is sampled by dipper. The weight of material treated is ascertained by specific gravity determinations made on a large sample caught during a definite period. I am unable to give analyses of concentrate and tailing, which would undoubtedly be instructive, if the management would release them.

Pine oil is introduced drop by drop into the first mixing cell. The consumption of oil is stated to be about 50 gal. per month, which is equivalent to about 0.4 lb. per ton of slime treated.

Miscellaneous Operating Details

The mill is operated one 8-hr. shift daily, with a force of fifteen men, and treats 200 tons per shift. Operations are controlled by means of the data obtained at the following points: The weight of ore fed to the mill is obtained from the Blake-Denison weigher, and the analysis of feed is made on the sample taken at

the end of the conveyor belt which brings the crushed ore to the mill from the crusher or ore-house; weight of concentrate is known and analyses are made on samples taken by pipe sampler from each car as it is taken from the concentrate bin; analyses of tailing are made on the sample taken by tilting box sampler from the

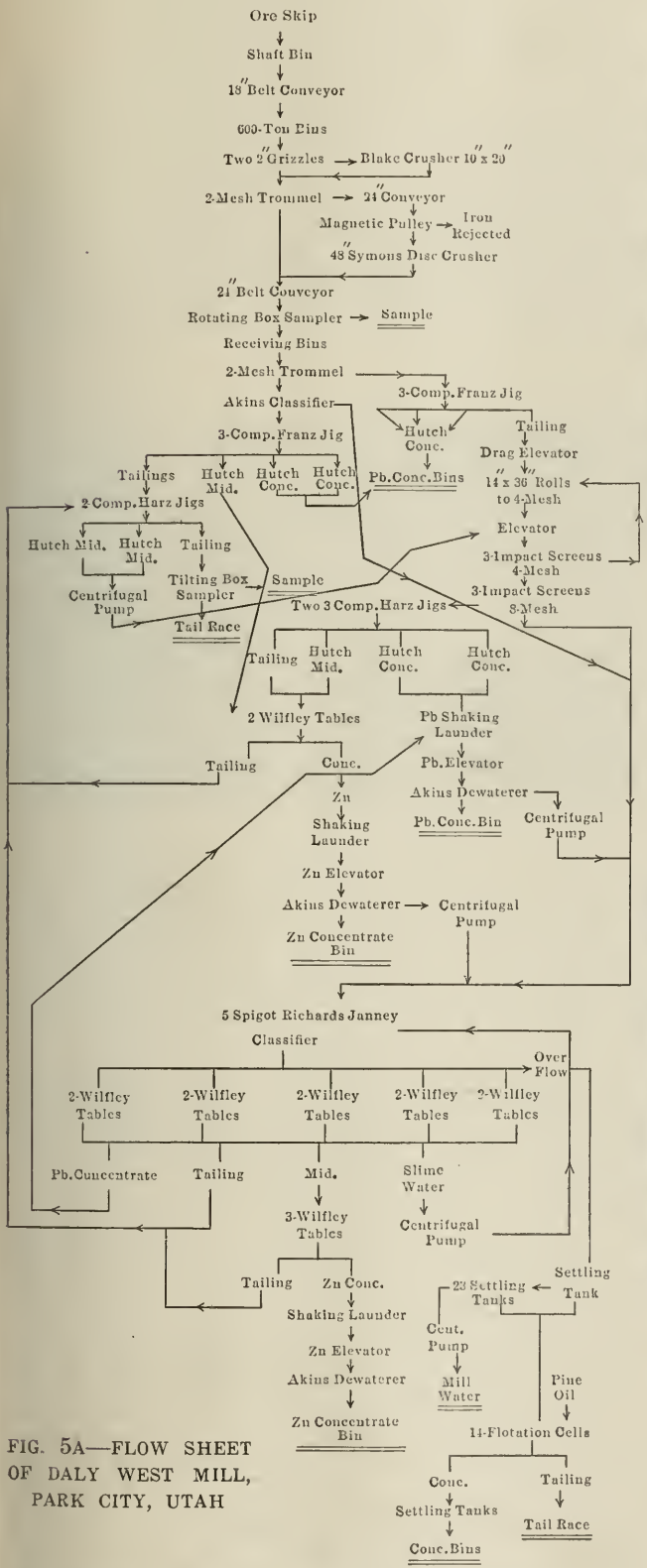


FIG. 5A—FLOW SHEET OF DALY WEST MILL, PARK CITY, UTAH

discharge of the tailing jig; the tailing from the flotation department, which does not go to the tailing jig, is sampled by dipper and the weight obained by specific gravity determinations made on pulp discharged for a known period. Regular samples are not taken during the course of the ore through the mill, but in case of any irregularity in the general tailing assay the suspected machines are subjected to a check sampling in order to remedy the trouble. As a result of this practice, I am unable to give figures on the work of individual machines, or on the grade of concentrate produced at different stages, or to give any information on the specific efficiency of different sections of the plant.

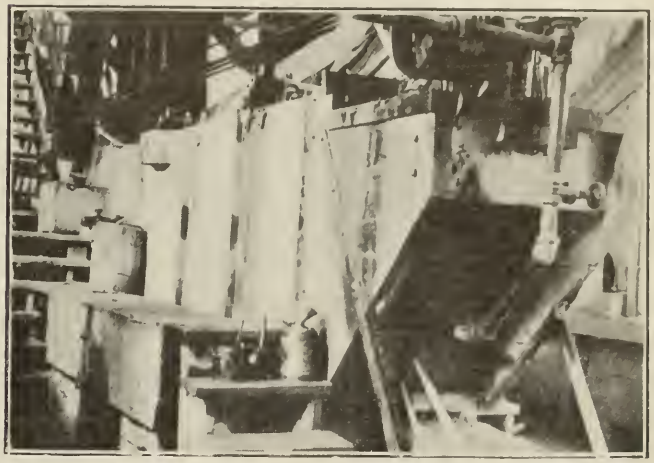


FIG. 6—FRANZ JIG IN DALY WEST MILL

Much of the equipment used in the new mill was salvaged from the ruins of the old. Head pulleys and belting for some of the elevators, classifier tanks, concentrating tables, shafting, conveying idlers, and some of the motors came from this source.

All tables now in use are the No. 5 Wilfleys, three Overstrom tables being held in reserve. The riffling is the No. 10 type, every other riffle being cut off a few inches short. In addition the so-called Thompson type

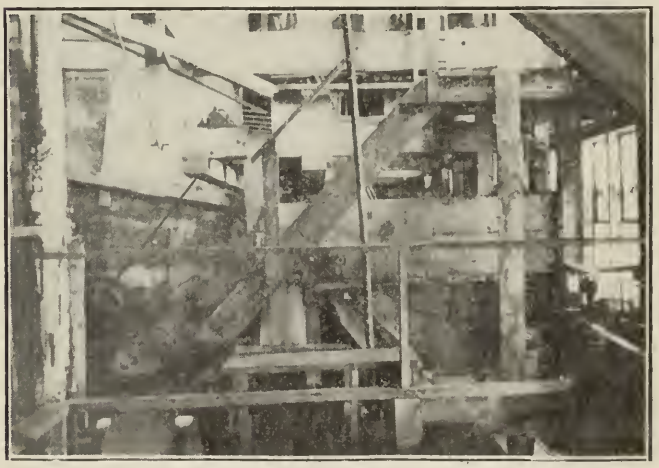


FIG. 7—FLOTATION CELLS, DALY WEST MILL

of riffle has been added. The alternate long riffles, which would ordinarily terminate in the well-known Wilfley diagonal, are extended a few inches upward toward the feed side of the table and then brought out parallel to the table to a second diagonal line. At other plants this type is said to have led to greatly increased capacity. Detailed figures as to results in the Daly West mill are not obtainable, although an average may be estimated by the reader.

Cleaning water is applied to the tables through perforations on the upper side of a two-inch pipe; this arrangement is shown clearly in the illustration of the lower table floor, Fig. 9. Water is brought from below

the floor to the tables, thus doing away with the overhead water pipes, and their attendant troubles.

The analysis of the metallurgical results of operation cannot be given until the publication of the annual report of the company for 1915, for the policy

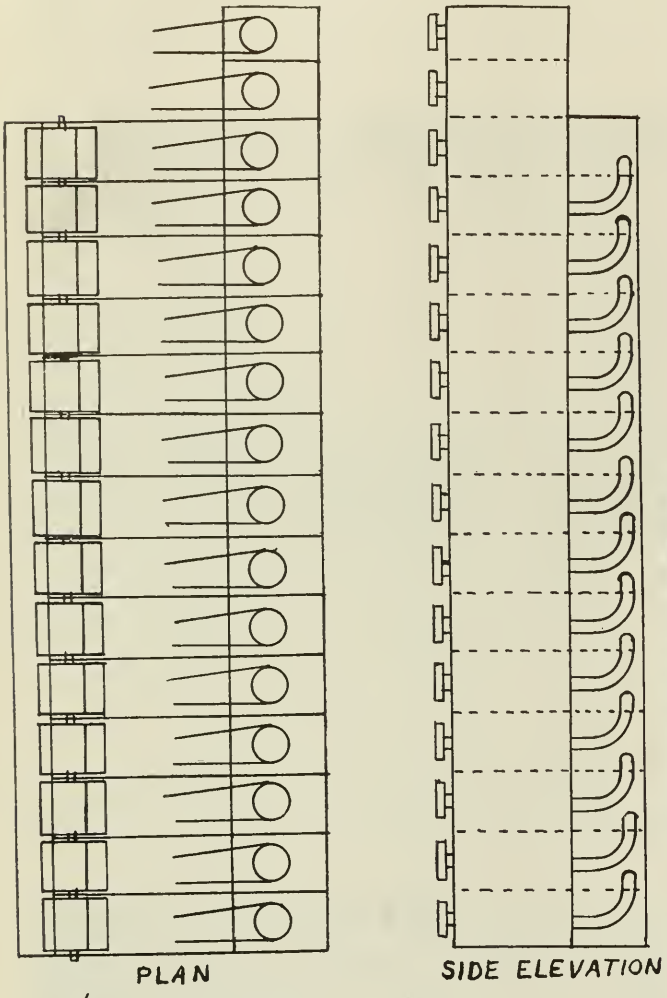


FIG. 8—FLOTATION APPARATUS, DALY WEST MILL

of the company has always been to give out but little information except through this source. However, a comparison of equipment used in this and the old mill may be of interest. Table 1 shows a list of the more important equipment in the old and the new plant side by side.

It will be noted that preliminary crushing and screening and regrinding units have been greatly decreased, as have the number and complications of the jigs. The number of elevators has been increased, but the load on them is diminished, as four of the elevators are for concentrates.

The compact flotation system has replaced the complicated classification and retreatment of slimes and has done away with the twelve slime tables. There still remain a large number of dewatering tanks preceding the flotation plant, used to thicken the feed to it. It would be interesting to know what a Dorr thickener would do if substituted for these numerous tanks. Of

TABLE I.

Equipment	Old Mill		New Mill	
Grizzlies	8	7 ft. long	2	6 ft. long
	1	4.5 ft. long		
Crushers	1	No. 4 Gates	1	10 x 20 Blake
	1	10x20 Blake	1	48-in. Symons
	2	14x36 Rolls.		
Elevators	4		5	
Screens	13		8	
Jigs	12	2-comp. Harz	2	3-comp. Franz
			1	2-comp. Harz
			2	3-comp. Harz
			2	3-comp. Harz (Reserve)
Regrinders	4	Sherman	1	14 x 36 Rolls
Settling tanks	11		25	
Classifiers	29	Sherman	3	Akins
			1	5-spig. Richards-Janney
Wilfley tables	14		15	
Slime tables	12		0	
Overtsrom tables	3		3	In Reserve
Flotation plant	0		14	Cells
Tonnage per 8 hrs.	190		200	
Men employed	20		15	

course they have the advantage of absolutely no cost of operation, little maintenance and cheap first cost, in this instance being already on hand. The chief disadvantage is the large floor area required for them. I do not know their efficiency, but assume that they do satisfactory work.

Hydraulic classification in the form of one Richards-

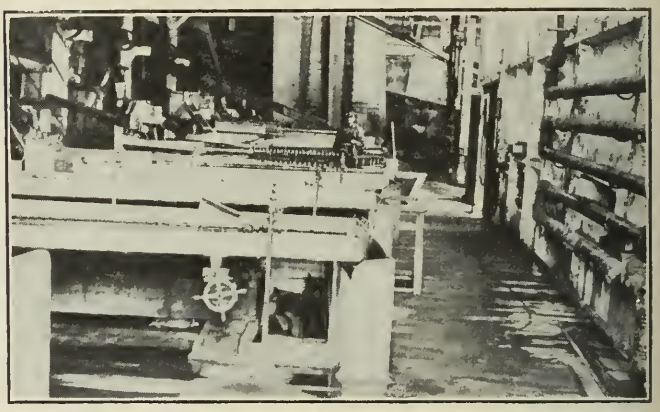


FIG. 9—LOWER TABLE FLOOR, DALY WEST MILL

Janney classifier has taken the place of numerous tanks in preparing the feed for the fine concentrating machines.

Milling water is obtained from lakes 1000 ft. above the mill and 3 miles south, being stored for mill use in large wooden tanks on the hill above the plant.

Power

Power is obtained from the lines of the Utah Power & Light Co. at 12,000 volts, and is transformed to 440 volts at the mill. The larger motor driving the crusher system is a Westinghouse, the others being General Electric. The list of motors follows:

No.	H.P.	Duty
1	75	Driving one 10 x 20 Blake crusher, one 48-in. Symons crusher, one trommel and 24-in. conveyor, 12 ft. long.
1	15	Driving 24-in. conveyor belt 210 ft. long, and one trommel
1	35	Driving one Akins classifier, two Franz jigs, and a tailing excavator.
1	100	Driving one set 14x36 rolls, Franz tailing trommel two centrifugal pumps, 15 Wilfley tables, Richards-Janney classifier, and four elevators.
1	40	Driving two Harz jigs, six impact screens, and one elevator.
1	50	Driving 16 propellors of the flotation machine, and 14 concentrate skimmers.
1	15	Driving one Harz tailing jig, and one centrifugal pump.
1	3	Driving 18-in. belt conveyor, 270 feet long, with drop of 12 ft.

The total horsepower installed is 333.

For the opportunity of visiting the plant I am indebted to H. G. MacMillan, general manager of the Daly West Mining Company; for courtesies extended at the mine, to E. L. Talbot, mine and mill superintendent, and for data used in this article and generous aid in preparing the flowsheet, to J. C. Thompson, mill foreman.

Salt Lake City, Utah.

Copyright, Pacific Photo & Art Co., San Francisco

San Francisco Meeting of the American Institute of Chemical Engineers

TO try and write the story of the seventh semi-annual meeting of the American Institute of Chemical Engineers would be trying to do something impossible. The best we can do is to give an account of the official proceedings of the San Francisco meeting, held from Aug. 25 to 28.

Of course, in such a dry record the real charm of the meeting is lost. Such charm is individual. Everyone who was happy enough to go West this summer has his own story—a story of meeting at the most unexpected places Eastern friends and sharing their pleasure and enthusiasm inspired by the West. On a fine Sunday morning the writer found himself sitting next to Dr. S. P. Sadtler of Philadelphia in a Santa Fé dining car in New Mexico; on the next morning, on the rim of the Grand Canyon in Arizona, he was stopped by the smiling face and outstretched hand of Prof. James R. Withrow of Ohio State University, and on the same afternoon, at Grand View Point, he met Mr. Ernst Boley of the American Steel & Wire Company, and so it went on until, in San Diego, he made connection with Dr. J. C. Olsen's official party of the American Institute of Chemical Engineers, including Professor and Mrs. Edward Bartow of the University of Illinois, Miss Bartow and Miss Abbott, Mrs. and Miss Darrah, Dr. E. E. Reid of Johns Hopkins University, Professor and Mrs. H. C. Enders of Cooper Union, New York; Dr. W. L. Klotz of the Barrett Manufacturing Company, New York; Mr. W. H. Ulrich of Cooper Union, New York, and Mr. H. E. Zitkowski of the American Beet Sugar Company of Rocky Ford, Col.

Of the San Diego days and the meeting of the Institute at Los Angeles we have given an account in our issue of Sept. 1. At San Francisco the headquarters were at the new and very comfortable Hotel Plaza, on Union Square. The three technical sessions on Wednesday, Thursday, Friday, Aug. 25, 26, 27, were held in the Civic Center Auditorium in San Francisco, in the chemical laboratory of the University of California in Berkeley, and in the chemical laboratory of Leland Stanford University in Palo Alto respectively.

On Wednesday afternoon an excursion was made to Protrero, where the oil gas works were inspected and the interesting new process of manufacturing oil gas was explained by Mr. Edward C. Jones.

On Thursday evening a subscription dinner at Tait's was immensely enjoyed, while Saturday was given over to an excursion to Winehaven, with inspection of vineyards and wineries.

It goes without saying that San Francisco outdid itself again in hospitality. While it is impossible to give credit to all to whom credit is due, Prof. J. M. Stillman of Leland Stanford and Prof. Edmund O'Neill of the University of California must be especially mentioned as untiring in extending courtesies to their visiting friends.

WEDNESDAY MEETING

The meeting at the Civic Center Auditorium was called to order by Prof. J. M. STILLMAN, who presided during that session. After a very cordial speech of welcome by the representative of the Mayor of San Francisco, there was a brief business session, in which it was decided that the winter meeting will be held in Baltimore and the meeting in summer, 1916, in Cleveland.

The first paper was then presented by Mr. A. M. MCAFEE on "The Improvement of High-Boiling Petroleum Oils and the Manufacture of Gasoline as a By-product Therefrom By the Action of Aluminium Chloride." This paper is printed in full on page 592 of this issue.

Dr. ARTHUR L. LACHMAN, the distinguished author of that charming little book on "The Spirit of Organic Chemistry," followed with a very interesting paper on "The Engineering Features of Wine Making." Limitations of space force us to withhold the abstract of this paper for our next issue.

THURSDAY MEETING

Prof. EDMUND O'NEILL presided at the meeting on Thursday in the chemical laboratory of the University of California in Berkeley.

The first paper presented related to "Costs as Applied to Professional Businesses," the author being Dr. RALPH A. GOULD of San Francisco. "The professional man sells service directed by systematic training in contrast to the unskilled workman who sells simply service, and in further contrast to the manufacturer or merchant who sells material. All are entitled to remuneration as a result of their labor. The first and the last are, furthermore, entitled to profit because of their in-

vested capital, in one case training, in the other capital. The profits of the professional man are mainly dependent upon his ethics and his ability at his profession, while with the manufacturer or merchant profits are largely the result of the laws of supply and demand."

Dr. Gould's paper describes in a very interesting way how with a partner in a consulting chemical engineering business they figure the cost of doing business. Their figures show the exact status of each client's business; how much they made or lost and exactly when they made or lost it; whether members of the firm are putting in too much time on unprofitable work and whether the connection with an unprofitable client should be continued on the same basis. They show the average profit derived from profitable clients and give valuable figures upon which to base estimates relative to new contracts and "overhead" clients.

Dr. Gould's paper is of considerable originality and deserves the attention of all consulting engineers and chemists.

Mr. EDGAR BARUCH of Los Angeles then presented a paper on "Resources and Possibilities of Chemical Industry in the Southwest." This interesting paper, which is published in full at the end of this report, elicited quite an extended discussion, in which Dr. Olsen, Mr. Beckman and Dr. O'Neill participated.

The last paper of this session was presented by Dr. OTTO BEST of San Francisco on "Manufacture of Cream of Tartar." This authoritative paper is published in full on page 613 of this issue.

FRIDAY MEETING

Dr. S. P. SADTLER of Philadelphia presided at the meeting on Friday in the chemical laboratory of Leland Stanford University in Palo Alto.

The following four papers were presented at this meeting:

"The Present State of the Thiogen Industry," by Prof. S. W. YOUNG.

"The Smelter-Fume Problem and Agriculture," by Prof. J. P. MITCHELL.

"The Purification of Sewage By Aeration in the Presence of Activated Sludge," by Prof. EDWARD BARTOW.

"Cottrell Processes of Electrical Precipitation," by WALTER A. SMITH.

Limitations of space force us to reserve abstracts of these papers for our next issue.

* * *

Resources and Possibilities of Chemical Industry in the Southwest*

BY EDGAR BARUCH

Generally the "Southwest" is designated as that portion of the United States lying west of the crest of the Rocky Mountains and south of the northern line of California, Nevada and Utah, a territory which includes all of these states as well as all of Arizona and portions of Colorado and New Mexico. The facts of this paper have been purposely limited to the confines of California and Nevada, though enthusiastic Californians might have suggested that the single name California be substituted for the "Southwest." Some "Native Sons of the Golden West" often state that were California to be severed from this continent or even the rest of the world by some cataclysm of nature, the State would in no way lack any of the natural resources which are the basis of the comforts and luxuries of modern civilized communities. This statement like many others emanating from California is difficult for strangers to believe, but is in reality not far removed from the actual truth. The following considerations may help to bear out this fact.

Geographically the northern boundary of California and Nevada extends 525 miles on lat. 42 deg. north; the eastern side of Nevada is on the 114th West Meridian; the southern line of California is about 32 deg. south lat.; and the western boundary of California extends along more than 800 miles of the shores of the Pacific Ocean in a general northwesterly by southeasterly direction. California alone curiously covers the extreme distances both north and south and east and west, and these are so great that they have an important bearing not only on great variations in climate, but also in transportation problems and the development of resources.

California has an area of 158,000 square miles and a population, according to the 1910 census, of 2,377,000—(not counting the rich tourists). Nevada has an area of nearly 111,000 square miles and only 81,875 population. Just for comparison note that the combined area, 269,000 square miles, are greater by more than 25 per cent than the total area of France with its 40,000,000 population, or Germany with its slightly greater area and 65,000,000 people, while California and Nevada have a combined population of only approximately 2,500,000, of which about half are rather closely congregated in comparatively small areas in the vicinities of San Francisco and Los Angeles.

Of course, the surface areas of California and Nevada are not comparable with those of France and Germany in the ability of those countries to support a large population per square mile, for not much more than one-third of the area of California is arable, about one-third is mountainous (though largely covered with timber) and the rest is desert, while almost the entire State of Nevada is barren waste of desolate desert and parched mountain ranges on which even jack rabbits and coyotes cull but the leanest pickings of a meagre existence.

The rainfall varies from almost nothing in the desert regions to 50 and 60 inches per annum in the northwestern counties of California. With but few local exceptions the climate is divided into a short wet period and a relatively long dry spell, but the large streams of central and northern California flow the entire year, fed by the everlasting snows of the high Sierras.

In California there are two great mountain ranges, the Coast Range Mountains paralleling the entire coast and the Sierra Nevada Range which runs from Shasta in the north to Tehachapi in the south. These mountains well above 10,000 ft. in altitude run at a greater continuous unbroken height than the Rocky Mountains. They culminate in Mount Whitney at 14,502 ft., the highest point in the United States outside of Alaska, and from this point, but for low intervening ranges 8500 ft. in height it would be possible to look down into the lowest region of this continent, the floor of Death Valley several hundred feet below sea level.

In the upbuilding and subsequent faulting of the continent the mountains, particularly the Sierras, were left with very abrupt eastern fasures and relatively gentle western slopes. This accounts for the general direction of nearly all California mountain streams being westerly; there are practically no large streams running toward the east. Between the great mountain ranges in California there is an immense valley, which converges toward its center to empty its drainage into the ocean through the "Golden Gate," the only low break in the Coast Range. The two branches of this valley, the Sacramento and the San Joaquin, are traversed

*A paper read before the seventh semi-annual meeting of the American Institute of Chemical Engineers, San Francisco Meeting, at Berkeley on Aug. 26, 1914. Very slightly abstracted.

by rivers of the same names which flow together in the delta region east of San Francisco Bay. The great valleys have been built up of thousands of feet of mountain erosion and owing to the variation in climate, ample water on the eastern sides, and rich soils, are highly fertile and adaptable to almost every conceivable crop. The costal valleys are relatively small, but numerous and conform in various positions between the spurs and ridges of the more or less irregular minor ranges. Those most important are Eureka, Santa Rosa, Santa Clara, Pajaro, Santa Maria, Santa Barbara, Ventura, the Los Angeles and San Diego and their tributary valleys and Imperial Valley. Owens Valley running north and south takes the small eastern run off of the Sierras which for ages collected in the basin of Owens Lake. This water is now being partially tapped from the Owens River as a source of water supply for Los Angeles City, by the great project of which you have all undoubtedly heard.

From a glance at the map you will note that the great desert of the State of Nevada is literally interlaced with one continual succession of short mountain ranges, nearly all of which run north and south. In between these ranges, owing to the lack of water, the floors of the valleys are rather steeply sloping with the detrius of boulders, rocks and sand of the slowly decomposing surrounding hills. In the entire State there is not one stream worthy of mention whose run-off ever reaches the ocean. In consequence such torrential storms as at times visit local districts, drain rapidly into pocketed basins or valleys, of which there are hundreds, where they ultimately evaporate in the form of dry lakes of concentrated alkali salts. These same conditions occur in like manner in the southern desert region of California where the saline deposits have been of more interest for no other reason than their more favorable geographic location.

Having thus shown you in a most cursory manner a few of the facial features of the country let us attempt to trace therefrom a few of the facts which have made these characteristics of such great value as natural resources of inestimable wealth.

TRANSPORTATION FACILITIES

There are harbors all the way down the coast from Eureka to San Diego. San Francisco possesses probably the most wonderful harbor in the world, large enough to shelter every vessel of the globe (even before the Germans and the English started their efforts to put ships at the bottom of the sea). There are splendid open roadsteads at Ft. Bragg, Monterey, San Luis Obispo, Santa Barbara, Santa Monica and Redondo and well-protected harbors at San Pedro and San Diego.

The San Joaquin and Sacramento Rivers are both open to transportation for several hundred miles.

Streams like the Trinity and Eel Rivers and the perpetually snow-fed streams of the Sierras, the Feather, Butte, American, Merced, Kings and Kern Rivers as well as a dozen others are some of them already furnishing hundreds of thousands of electrical horsepower and are capable of supplying millions more.

MINERAL SUPPLY

The ribbed and scarred mountains besides being the source of water-power and timber offer an infinite array of minerals.

The "49ers" in their mad scramble for gold overlooked most other metals, minerals and resources. It was not until the discovery of the Comstock Lode that attention was even devoted to the silver lead ores and nearly fifty years elapsed before any copper was produced from the Shasta district and later in Nevada at Ely, Ludwig and other places. There are numerous reasons for the slow progress in the development of the mineral resources; transportation facilities were lacking; the technique of handling and milling ores was crude; cyaniding was unknown, which made only placer and free milling gold ores of high value available; water-power could only be utilized from wooden wheels at dam sites, and steam power by the expensive use of wood as fuel in timbered districts. Because coal oil and gas were unknown smelters did not exist and processes for handling complex ores have only been developed during comparatively recent years, by the concerted efforts of the chemists with the mining engineers—efforts which are still proceeding with unflagging energy and are daily budding into new and successful processes and methods. Think, for example, of the development of the Pelton and turbine wheels for power, the marvelous evolution of the dredges, the economies of the cyanide processes, the Cottrell improvements for obviating smelter fumes and the new processes for leaching copper ores.

The California gold production since 1850 has amounted to $1,600,000,000 and is still nearly $20,000,000 per annum. Nevada has produced $400,000,000 and now furnishes $12,000,000 gold annually. The low prices of lead and silver put such a quietus on the production of these metals that their important deposits have been all but forgotten.

California and Nevada still produce more than 85 per cent of the quicksilver from the United States, about 15,000 to 18,000 75-lb. flasks per year.

Platinum has long been found in the sluicing and dredging operations on the Trinity River and northern streams of the Sierras, but no consistent efforts were ever made to trace the occurrences to their sources. Quite recently some enormously rich deposits have been found in conjunction with zinc, in the Good Springs country in southern Nevada. Pockets of ores have been found running as high as $11,000 platinum, palladium and gold to the ton. The fact that the ore looks like a rusty clay probably accounts for ignorant prospectors having tramped over the ground for many years without cognizance of the wealth beneath their feet.

The zinc regions thus far known seem to be fairly well concentrated from Ivanpah to Good Springs. The occurrences are in the form of both calamine and sphalerite.

Tin was developed from cassiterite ores at Temescal in Riverside County some years ago, but the deposits are now lying idle.

Antimony has been long known, but shipments have only recently been started and a smelter is now in operation at San Pedro.

Bismuth has been found in veins south of Banning, and arsenic occurs frequently with gold ores on the Mother Lode. Chrome is found in large quantities on the western slopes of the southern Sierras.

Manganese is almost of common occurrence. The largest deposits are in the Coast Range mountains of Tehema and Mendocino Counties, at Tesla in Alameda County and in the Chocolate Mountains of Riverside County.

A Los Angeles engineer recently published a most illuminating article on the iron deposits of southern California in which he shows that by the most conservative estimates there are over 200,000,000 tons of iron ores available in the Providence, Eagle and Kingston mountains, all adjacent to railroads. The deposits average 64 per cent iron content against 55 per cent ores from the Mesaba Range, and there are fewer impurities, such as phosphorus, sulphur and silica. Is it not remarkable that with a yearly consumption of 900,000 tons of steel, and with limestone, fuel and nearby coke available, that these deposits remain untouched?

Not far distant from the iron are manganese and the only working deposits in the United States of tungsten. The electric smelting of iron at Heroult proved too expensive to be practical and the plants have been given over to the production of ferro-manganese. We have thus far badly neglected our opportunities of furnishing this country with high-grade steels.

The extent of the limestone formations, even in the southern sections, alone, almost beggar description. At Sloan, Nevada, range after range of mountains stand hundreds of feet above the floor of the desert solid unbroken masses of high-grade limestone. At many other points westward all the way to the coast there are hundreds of millions of tons of exposed lime rock. Big cement plants are to be found at Oro Grande, Colton and Riverside, also in the north at Santa Cruz, Napa Junction and Cement, while the lime deposits occur in the mountains all the way to the northern boundaries of the State.

Relatively, magnesite is of but small occurrence, though Califronia is the only State in the Union producing it. There is a small deposit at Winchester, a larger occurrence near Mojave and mines are now being worked near Fresno, at Red Mountain and in Sonoma and Napa Counties.

Kaolin, china porcelain and pottery clays are found at Ione in Amador County and Placer County with feldspar and silica not far distant, yet California imports yearly $300,000 worth of china and porcelain from the East. Brick and tile clays occur in river bottom lands in sections too numerous to mention. From the dark heavy clay soils of the ground on which they squatted the early Spanish and Mexican settlers made sun-dried bricks, from which they built their adobe huts.

Silica in the form of quartz can be obtained almost everywhere and there are fine deposits of white silica for paints and glass-sands in Nevada.

Sulphur was mined for many years in Humboldt County, Nevada, and fairly large occurrences are just south of Goldfield, while a very large new discovery has just been reported from Kern County.

Most of the world's supply of borax comes from California, from the great Borax Smith mines in Death Valley and more recently from the Ventura County deposits of colemanite.

The deserts furnish gypsum, talc, celestite, baryte and salt in profuse abundance and the dry lakes contain untold millions of tons of soda in the form of both carbonates and sulphates. At Searles Lake, of unfortunate exploitation, the American Trona Corporation spent more than $500,000 for a railroad before they had so much as evolved a process for working their raw materials. They planned to recover from the lake brines primarily potash, also sodium carbonate, sodium bicarbonate, sodium sulphate and borax. Many of the sinks of Nevada contain a considerable amount of potash; and much harmful exploitation and ill-directed effort has been expended trying to obtain potash from the sea weeds and kelps of the coast, from which the companies have hoped to recover iodine as well as many organic materials.

Throughout the two States there are small or sporadic deposits of flourite, bauxite, molybdenite, nitre, graphite, mica, asbestos, jasper, ochre, pyrites and alum, not to mention a hundred other less important minerals.

Mineral water and springs of all descriptions, hot and cold, mud, sulphur, soda, salt and lithia are to be found.

San Diego County furnishes us with the lithium salts of lepidolite from Pala, and from the same region are derived the semi-precious gems of tourmaline, aquamarine and kunzite. Elsewhere we obtain moonstones, garnets, tourquoise, onyx, opal, sardonyx, crysoprase, cat's eyes, variscite, rhodenite, californite, beryls, topazes, jades, abalone and pearls, even sapphires and not to be behind Arkansas occasional diamonds are noted.

Fuller's earth, little of which has been utilized occurs in Nevada and in the San Joaquin Basin.

There are numerous deposits of infusorial or diatomaceous earth in both California and Nevada. Probably the finest and largest deposit in the world is at Lompoc in Santa Barbara County. Through the efforts of the owners and their research chemists the value of their product has been demonstrated in many different industries. According to the specific gravity and purity of the material it is used in such diverse fields as the manufacture of sugar, edible fats, light brick, as an insulating medium, etc., some forty patents having been applied for or issued within the last few years covering the applications of their products to new uses. This is only one indication of the possibilities of well-directed chemical industry in the use of heretofore disregarded material.

We have an abundance of building materials such as slates, rhyolites, trachytes, volcanic tuffas, obsidianites and basalts. Marbles are plentiful, but quarries near existing railroads generally appear to be badly faulted and shattered, though the main difficulties in obtaining good slabs can usually be attributed to the ignorance with which our western deposits have been worked. Excellent varieties of colored, veined marbles are found at Carrara, Nevada, and green malapi conglomerates are obtained from near Barstow. All forms and colors of granites and sandstones are available of which you have seen many beautiful examples in the buildings of Los Angeles and San Francisco. Our cities need not go as far as Rome went, for their paving blocks, macadams, rubbles, gravels, sands and building materials.

OIL

In some of the valley regions there are large deposits of peats. Lignites and coals occur in the Coast Range Mountains. But of far more vast importance to chemical industry have been the discoveries and development of petroleum oils and natural gas during the last twenty years. With a production of 7,000,000 to 8,000,000 bbls. of crude oil per month no one need longer worry about any possible lack of fuel supply for our industries. California has at this writing approximately 55,000,000 bbls. of oil in storage above ground. Since the inception of the industry in 1890 approximately 750,000,000 bbls. have been produced and nearly 90 per cent of this amount within the last ten years.

We are refining as much of our oil as the markets will take and make casing head gas, gasoline, kerosene, distillates, lubricants and asphalts, but in view of the enormous sources of hydroelectric energy available for power it would appear that in burning our surplus oil we are practicing a criminal wastage of our resources for which we can hardly expect our descendants to forgive us. We have indeed been unwise as well as profligate with our heritage of natural wealth, to an extent from which we of the younger generation and our immediate children will suffer the effects. This condition applies particularly to our careless even wilful wastage of natural gas encountered in drilling for oil and which we in our haste for the nearest dollar have allowed to escape us to the cost and comfort of future generations. To be sure we are now beginning to pipe some of the excess gas from the wells to the cities, but distances in this country are great, investments large and subsequent prices for the gas are high.

Water gas from crude oil is the basis of most of our artificial supply. The only efforts made to utilize the

by products of this industry are in the making of carbon briquets; the napthalines, pitches and tars are all wasted.

The increased use of direct combustion oil engines of the Diesel or semi Diesel type should do much to effect economies in the consumption of oil fuels.

The shortness of my time limits more than the mere mention of such well established industries allied to the mineral resources as acid and powder manufacture, the production of fertilizers, glass and heavy chemicals.

With this hop, skip and a jump I fear that you have gained only a very faint conception of the extent and variety of our mineral products, but suffice it to say that of these materials California alone produced $103,000,000 worth in the year 1914.

AGRICULTURE

Agriculturally the resources of Nevada are too small to warrant attention at this time, but California more than makes amends for the deficiency.

The great valleys which twenty years ago supplied little more than grain and cattle are to-day undergoing constant transition toward more intensive farming and diversified crops. Wheat, barley, oats and corn are still grown in enormous quantities and now-a-days large crops of rice, on what were formerly called goose or bad lands. Hops for the brewing industries occupy much of the bottom areas of the Sacramento basin. One will find vineyards all the way from Red Bluff in the north to Bakersfield in the south, with the attendant industries of raisin growing, wine making and sometimes the production of argols. Interspersed with the vineyards you will see orchards of cherries, almonds, peaches, pears, apricots and prunes. Asparagus, potatoes and vegetables of all descriptions are grown on the river islands and deltas. The valley foothills grow olives, lemons, oranges and grape fruit, and in the higher altitudes the best of apples.

South of San Francisco, along the coastal valleys as far down as San Juan Capistrano, approximately 125,000 acres of sugar beets are planted annually, which yield about 500,000,000 lbs. of sugar, an amount two and one-half times in excess of the needs of our own population, not counting the equally large output of Hawaiian sugars from the two refineries on San Francisco Bay. Chemically and technically the best sugar industry has reached a high state of perfection though there are still many opportunities for improvements, particularly along the line of investigative agricultural chemistry and in the utilization of the waste products. The plants which have only molasses as an end product sell their material to either alfalfa-meal mills or to the distilleries for the production of alcohol. Those plants which have installations of the Steffens recovery process, in general, still send their waste waters, which contain distinctly valuable amounts of potash and nitrogen, to the sewers. In one or two instances these waters are pumped on to the fields as fertilizer, other plants are making efforts to concentrate their waste waters in conjunction with their lime cakes for the production of marketable fertilizers. About 3.5 tons of potash have heretofore gone to waste with every 1000 tons of beets worked.

The southern valleys, generally subject to fogs during the summer months, are well adapted and produce, in addition to sugar beets, large crops of beans, walnuts and olives. A recent improvement in the olive industry is a process for extracting tannic acid by drying bruised fruit—or mincing the meat, boiling it in its own oil and canning the product. In addition to the production of olive oil we grow peanuts and make the oil and butter therefrom. A fact not generally known is that California is producing annually about 600,000 lb. of Turkish cigarette tobacco.

The citrus products for which southern California is so well known are grown in the foothills and the semi-high regions where the orchards are least affected by the frosts. It is only of recent years that much attention has been paid to the possibilities of utilizing the fruits to the fullest advantage, particularly the so-called culled fruits. The associations of growers are maintaining separate laboratories, besides the special government stations, attempting to work out processes for the production of citric acid, oils of orange and lemon, citron, candied peel, marmalade, orange butter, orange wine and orange syrups.

The new farming districts of Imperial Valley produce alfalfa, cattle and cantaloupes. The finest grades of long-staple cotton are grown in this district and the cottonseed oil and cake industry is naturally following in the wake.

The fishing and canning industries along the coast are worthy of special mention. Sardines from San Pedro have for many years been boiled in California oil and put on the market in French-looking cans. But an industry, all our own, established at the same point is the production of canned tuna. Salmon have been caught in the Sacramento and the northern coast streams since the beginning of our history. Oysters, the small varieties, quite different from the large eastern type, are found in the bay regions.

The gradual encroachment of orchards and intensive farming on the old princely estates of the land barons, who formerly owned 40,000 to 60,000-acre tracts, has also demoralized the old-time cattle ranches of the low lands. The grazing grounds have been gradually driven further back into the hills and mountains, and only when the grass becomes short or the cattle are to be fattened for the markets are they herded into the valleys for alfalfa, grass or grain feeding. Dried beet pulp is also attracting considerable attention and the entire output of three of the southern beet sugar factories is either steam or kiln dried and sacked for dairy fodder; other mills pump the extracted beet slices to silos where the water drains off in part and the remainder after souring is highly valued for cattle fattening.

Our packing house industries are, of course, diminutive compared to those of the Middle West, none the less we have our tanneries, soap works and other allied branches of this work. It is, however, worthy of note that our hides all go East to be made into shoes which have to make another trip across the continent for our use. The majority of our wool and cotton follow the same course. The only textile mills we have weave cotton bags and canvas. . . .

You have probably already been wondering why this brief catalog of our resources and industries is so lengthy. I have been trying to convince you with a short survey that Californians can make good their boast that they lack no resources to make and supply them with all necessary physical comforts. Nature was probably never more bountiful to any country than this Golden West. We possess the resources for great industries based on electrochemical, metallurgical, mineralogical, agricultural, horicultural, husbandry and forestry pursuits.

PRESENT INDUSTRIAL LIMITATIONS

Why have these not been more firmly established and grown to greater extents? Why do we ship our crude products to the east and foreign countries for fabrication without even taking through the gates of our cities, to have them shipped back to us in only slightly altered form for our consumption? Why are our harbors only

transient points for all the riches of the tropics and the orient? Why have we been so slow to realize and to utilize to the fullest extent the resources, and to materialize into tangible assets the long dormant possibilities of our western kingdom?

The reasons are numerous. View our "splendid isolation" with the vast Pacific on one side of us, high mountains and broad deserts on the other, an almost barren uninhabited peninsula on the south and long reaches to civilization on the north. There are only four mountain outlets from California, ranging from nearly 4000 to 7000 feet in altitude. Bear in mind that we are more than 3000 miles from the eastern seaboard, 2000 miles from the center of population in this country; that it takes 6 days to reach Hawaii, the nearest islands of the Pacific, and three weeks to Japan, China or the Philippines, by fast mail boats.

Our Empire is traversed by only three trunk line railways with but few branch and spur line ramifications into the surrounding territories, and these lines largely parallel each other. In consequence, ore and timber deposits, with the possible exception of precious metals, are almost valueless unless by chance they lie practically adjacent to existing transportation. It is impossible to haul salt, gypsum, talc, magnesite, soda, potash, chrome or manganese from 10 to 50 miles over desert or mountain roads with any hope of putting such products on even the local markets at a profit. The first question asked of the prospector is "how far are you from the railroad?" Though we still have amongst our population many hopeful prospectors, sturdy mountaineers and tanned desert rats, they have mostly learned that excepting for gold they cannot wander far from the iron rails. In consequence there are still great undiscovered almost virgin regions in both California and Nevada.

Irrespective of long hauls to the railroads we have had much to contend with from the railroads themselves. No better picture of this phase of our development, has ever been penned than by Frank Norris in the "Octopus" in which he vividly describes the bitter hatred of the California pioneers for the Southern Pacific Railroad of the days of Collis P. Huntington. Though the old railroad tyrant has been long dead they failed to bury all railroad abuses with him. However, since the Harriman régime the Southern Pacific Railroad has improved wonderfully and the competition of the Santa Fe and the Western Pacific and the State and Interstate Railroad Commissions have done much to better conditions.

I am informed that in the east it is possible to generally figure 3½ mills per ton mile on railroad haul for ores. The lowest rates of which I am aware in this country are 5 mills per ton mile on certain sections of the Santa Fe. The beet sugar people pay 7 mills per ton mile for 70,000 tons of rock per annum over 197 miles of track. Recently I had some cheap ores (silica) to be moved 200 miles in Nevada. The first quotations were $15.90 per ton, and it took much coercion and many weeks of voluminous correspondence to ultimately obtain a rate of $3.90. If you desired to ship desert sand or ordinary rock from Nevada 400 miles to Los Angeles you would have to pay $4.00 per ton freight (10 mills per ton mile); to San Francisco, 500 miles, you would have to pay $6.00 or 12 mills per ton mile. The glass factories in the bay region claim that they pay only $5 per ton for Belgian sands after they have been transported 20,000 miles.

The lowest ore rates to the East via the Panama Canal are $7 per ton. Via Galveston on the Southern Pacific there is a $10 rate, but all material must be sacked. The lowest all-rail rates are $12 per ton. This is sort of a blanket rate to the majority of the railroad centers throughout the country. It costs $12 a ton to ship low-value ores to New York, Boston, Chicago, St. Louis, Denver or Salt Lake City and as anomalous as it may sound you might have to pay anywhere from $15 to $18 per ton if you wanted to stop your shipment at any point before it reached even Salt Lake City, the nearest terminus.

Our labor problems present many difficulties. With the total exclusion of the Chinese and the restrictions on Japanese, Hindoo and Mexican laborers we have discouraged and retarded many big enterprises. We are in need of foreign labor, a moderate number of thrifty Chinese or busy Japs would be of decided advantage to this country. We do not need Greek and Neapolitan fruit venders or organ grinders to crowd our cities, but we do need fruit pickers and mill workers.

Life in the rural and mountain regions is generally most attractive. Hunting and fishing still abound and there are good roads thereto in almost every section.

The city conditions are not much different from other parts of the United States. San Francisco as a world harbor is very cosmopolitan, a small New York. For many years it has been burdened like the old man of the sea with Unionism and labor troubles, yet see with what majesty she recovered from her devastating ruins. Los Angeles, a very moral town, is the next to the last abiding place of most of the successful farmers of the Middle West and many other people who can raise the cash to pay the railroad fare to what they think is a land of ease and indolence. The chief industries of this branch of the population are real estate and insurance.

I trust that I may have conveyed to you that we produce a far greater quantity of raw products, fruits, sugars, cereals, textiles, timbers, fuels and minerals than the people within our own borders can consume. The difficulties which lie in the way of hindering more rapid development are the lack of sufficient and reasonably priced transportation facilities for getting our products to markets. The sparsely settled country and the lack of population particularly of working classes, is the cause not only of restricted *local* markets but also of high labor costs for all products. The newness of the country has called for immense outlays of capital for development purposes, but investments in our big industries seem to be attractive to even foreign money as is witnessed by the interests of the Dutch Shell Oil Company and the General Petroleum Company in our oil resources and there is also much foreign capital invested in our copper and gold mines. We still need vast sums to help sane, rational development, but we trust that we shall no longer be oppressed with the scandalous exploitation schemes of scoundrelly promoters.

There are at present more pregnant opportunities for the development of resources than in the days of the pioneers of '49. We are only in need of much strong, honest effort and staunch capital to back it to make this one of the richest countries of the world.

It is frequently said that when one once visits California the longing to return never ceases until one comes back to live. We hope *you* have caught the lure of the "Golden West" and that we will some day see all of you chemists and engineers, you men who accomplish things, back amongst us in the near future, helping us with your hands and brains to change our possibilities into realities, and helping us to put to the best uses of mankind our great resources.

The activity of Japan in mining is represented by the fact that there are more than 1500 mines in operation, 52 gold, 112 gold and silver, 53 silver, 175 copper, 536 coal, 161 oil. Others are antimony, iron, manganese, graphite, peat, sulphur, etc. Many employ the most modern machinery.

The Fleming Dust Collecting System*

BY W. C. HANNA

As visitors pass out of the large acreage of orange and lemon groves owned by the California Portland Cement Company, and come within closer view of the splendidly equipped mill at the foot of Slover Mountain, those familiar with the general appearance of cement manufactories notice a decided difference in this one. There is something lacking which is common to the industry—or has been in years gone by. There are no kiln and dryer stacks with their objectionable trail of dust and fumes.

How it is possible to have such a condition in a factory of this size is explained by the buildings at one side of the plant, from the end of which large volumes of water vapor are pouring. These buildings and the machinery connected with them constitute the Fleming patent dust collecting system, which is receiving much attention from cement manufacturers throughout the United States, and back of which lies a history of interest to all connected with the cement industry.

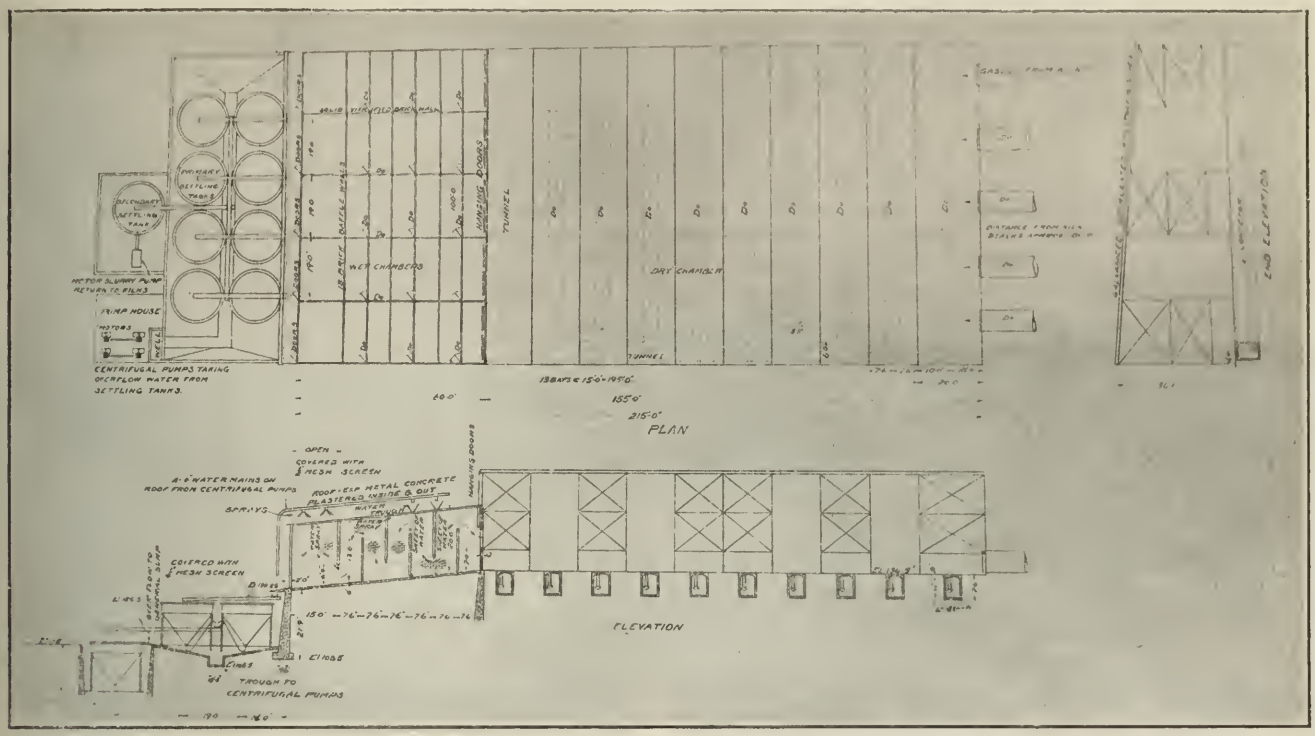


FIG. 1—THE FLEMING PATENT DUST COLLECTING SYSTEM

Orange growers in the vicinity of Slover Mountain began to complain in 1909 about dust emanations from the kilns and dryers of the cement plants operated at Colton. At that time the new or largest plant was one of the most modern in the United States and was considered by cement manufacturers a clean plant, and as there had never been any recorded injury to people or vegetation in the neighborhood of cement mills, the orange growers' complaints and threats were believed to be without grounds, but serious enough, however, to warrant an extensive line of investigations and experiments with all known methods for capturing the dust.

These investigations were continued with zeal, but nothing of sufficient effectiveness was found. In the meantime the orange growers, not being satisfied with the efforts of the cement company, brought suit against it and, in the trial during July and August of 1910, expert testimony from many parts of the world covered much of the field of cement manufacture, dust collecting devices, and agriculture as practised in the vicinity of Colton.

The Superior Court granted the orange growers an injunction in April, 1911, which became effective in June of that year, but, by that time, experiments at the old cement plant had proved so satisfactory that Mr. T. J. Fleming, secretary and general manager of the company, had most of the material on the ground for constructing his dust collecting system on a practical scale for five rotary kilns $7\frac{1}{2}$ ft. in diameter and 120 ft. long. By September, 1911, the first kiln was operating to the dust house and, shortly afterwards, all of the kilns were operating at full capacity with the Fleming System. Meanwhile, throughout the mill, a campaign against dust was made, resulting in all grinding machines, elevators, and conveyors being made practically dustless.

The orange growers were not yet satisfied with the efforts of the Cement Company and brought suit for contempt of court. The evidence was such that the court was not satisfied, so he appointed Dr. R. E. Swain of Leland Stanford University, as an impartial expert to make an examination of the system and report to him.

Dr. Swain's very complete investigations were made in February, 1912, and the report, which he made shortly afterwards, was so favorable that the court dismissed the case stating that the plant as operated was not a nuisance and was not being operated in contempt of court.

This same system of dust collecting has been in continuous use since that time and has proved to be, not only an efficient means of capturing the dust, but also to be more than self-supporting, there being a saving to the company in the dust captured, better output per barrel of fuel oil, and less shut downs than before the Fleming System was in operation.

*A paper read at the seventh semi-annual meeting of the American Institute of Chemical Engineers, at Los Angeles, California, on Aug. 18, 1915, in joint session with the Southern California Section of the American Chemical Society. An account of this meeting was given in our issue of Sept. 1, page 530.

PRINCIPLE OF SYSTEM

Very briefly, the installation consists of normal rotary kilns using dry process and oil for fuel. The draft for the kilns and dryers is produced by fans sucking at the end of separate flues. Instead of discharging the gases into the atmosphere, the same exhauster fan blows the dust and fume into a large chamber known as the dry dust settling chamber where the velocity of the gases is reduced about 90 to 95 per cent, resulting in a large amount of dust being deposited. The extremely fine dust which does not settle and the gases then go to the wet washing chambers where the gases are forced up and down several times while following a serpentine course through a system of seven baffle chambers, and the last of the original so-called cement dust is captured by sprays of water which are in each chamber. These sprays of water also bring into solution much of the gases, lime and alkalies. In connection with both the dry and the wet chambers there are means provided for removing the captured dust to the cement kilns.

DESCRIPTION OF PLANT

This paper will describe a unit in connection with three kilns 8½ ft. in diameter and 150 ft. in length with a capacity of 31 barrels of clinker per kiln hour, or about 2200 barrels per day, also one clay dryer which handles all of the clay used at the plant. This is the third large unit installed at Colton, each new unit, as installed, having a few improvements over the preceding one. The house has capacity for two more kilns of this same size.

FIG. 2—THREE KILNS AND FLUES LEADING TO FANS

The clay dryer flue is seen below the three large flues. Part of dry dust chamber shown in lower right hand part of picture. Sawed off stacks, with seal on top for five kilns 7½ ft. by 120 ft. seen in the extreme left.

The fans which produce the draft in the kilns are located at the end of what would normally be the stacks to the kilns, but which in this case are about 180 ft. long and which, instead of being perpendicular, first rise from the stack base at the feed end of kiln then curve over and slope downward toward the fans. Each kiln is provided with a separate flue, fan and motor, so that the operation of any one kiln is independent. The flues are 6½ ft. in diameter, lined with fire brick for the first 20 feet, and they are provided with the necessary expansion joints.

The fans are of special exhauster type made by the B. F. Sturtevant Company. They are 5 ft. wide and 10 ft. in diameter, equipped with water cooled bearings and operate at a speed of about 145 r.p.m., each fan being driven by a 40 hp. motor, although only 11.7 hp. is required except when fan is first started. During the past year of continuous service there has not been a single hour lost due to fan trouble.

The results obtained by the kilns determine the speed at which fans are to be operated. Sometimes it is found to be desirable to give the kiln more draft, and the fan is operated at a faster speed, while at other times the reverse is true. The ease with which the draft in the kiln can be regulated is of great assistance in the economical operation of the rotary kilns.

A Thwing pyrometer is used in connection with the installation, the thermocouples being located in the flues near the fans, and the recorder in the kiln room where the cement burners can regulate the fires keeping the temperature at the fans not higher than 900 deg. Fahr. This together with the perfect control over the draft and of the speed of the kilns, makes the condition ideal for the manufacture of Portland cement clinker. The draft, induced as above, has proved to be far easier to control than a stack draft, the life of the kiln lining is almost permanent, provided kiln is not allowed to get cold, the ring formation reduced, and the clinker produced more uniform in quality.

DRY DUST SETTLING CHAMBER

The discharge from the fans is just about the same as from an ordinary kiln stack, only the blast is horizontal instead of perpendicular and at an elevation that is convenient for treating the gases laden with dust in the dry dust settling chamber.

This chamber into which the fans discharge the gases is 150 ft. long, 100 ft. wide and 31 ft. high. It is a steel frame structure, with sides and roof covered with corrugated galvanized iron in order to promote radiation of heat.

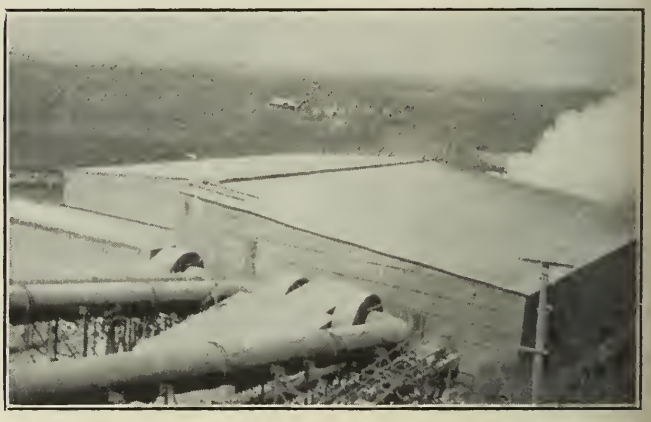


FIG. 3—THE FAN WITH PART OF FLUES

Also dry dust chamber, and water vapor pouring from the wet baffle chambers.

There are no barriers to a free passage of the flue gases within this chamber, except a set of baffle plates about ten feet wide extending across the chamber in a line about thirty feet in front of the inlet flue openings.

The temperature of the gases as they go to this chamber is 700 deg. to 900 deg. Fahr. and on emerging from the same the temperature is 300 deg. to 400 deg. Fahr. Due to this reduction of temperature, and to the large area of the house there is a 90 to 95 per cent reduction in the velocity of the flue gases, resulting in about two-thirds of the suspended dust particles or about thirty to forty tons of dust per day being deposited in this dry chamber.

There are ten cross tunnels beneath the floor of this department, and in each tunnel there is a screw conveyor with steel troughs and ten spouts, with gates, leading from the floor above into the conveyor for drawing off the dust.

Each of these cross tunnel conveyors discharge into

the conveyor running in the main tunnel and it, in turn, connects with a conveying system which carries the dust to a bin in the raw mill building. The dust is drawn from this bin and properly mixed with the material being fed to the kilns.

WET WASHING CHAMBER

The gases, with the remaining dust, go to the wet baffle chamber which is the same width as dry chamber and 60 ft. long. The frame work is of steel, the sloping floors are of concrete, the walls of brick and concrete, and roof of expanded metal encased by concrete.

It is divided into five separate compartments, each 60 ft. long and 20 ft. wide.

Each compartment receives the gases from the dry chamber through two openings, 6½ ft. by 9 ft., which may be closed by means of hanging concrete doors operated vertically from the roof.

Only three of these compartments are required and the two not in use can be kept in reserve in case any of the others should require new sprays or other work done on them.

Each of these compartments has six transverse baffle partitions alternately rising from the floor and descending from the roof, leaving six foot transverse openings through which the gases are forced, over the first baffle and under the second, and so on until they

FIG. 4—DRY CHAMBER AT LEFT, THEN WET BAFFLE CHAMBERS, THEN SETTLING TANKS

pass under the sixth baffle, emerge into the exit chamber, and through the roof, which is made of one-half inch mesh wire screening. The actual area of exit openings for each compartment is about 135 sq. ft. and the velocity of the gases about 250 ft. per minute.

Each baffle section in each of the five compartments is provided with a set of water sprays. The return water from the settling basins is used in all of the sections except the last one. Each spray with return water is adjusted to carry about twelve gallons of water and each fresh water spray delivers about six gallons per minute. In these wet baffle chambers the remaining one-third of the dust in suspension is removed and the temperature of the gases reduced to about 125 deg. Fahr. at the exit.

The water with its load of dust, falls to the sloping floor and runs to the end of house, where it falls into a screen covered trough extending the entire length of the end wall of the wet baffle chamber. Lateral troughs lead from this to the center of each of the eight primary conical, steel, settling tanks, 16 ft. in diameter.

The overflow from these, being almost free from suspended matter, falls through the open air, in order to cool it, to the reservoir below from which it is pumped as return water at about 100 deg. Fahr. by centrifugal pumps, back to the sprays.

The thin slurry from the bottom of the conical primary settling tanks is syphoned through gooseneck pipes to a common trough which leads to a secondary conical settling tank.

The clean overflow from this also goes to the common collecting reservoir, but its thick slurry, containing about twenty pounds of solids per cubic foot, is pumped to the slurry tank above the kiln stack bases from which it is continually fed to the rotary kilns.

The amount of water required to operate the Fleming system is much less than at first would be expected. The fresh water need not exceed 75 to 100 gal. per minute, and it has been found desirable to add this in the form of coarse sprays in the exit chamber, above the screen to the same, and in the baffle chamber just before exit chamber. The greatest part of the washing is done by the circulating water which amounts to at least 1000 to 1200 gal. per minute. The heaviest sprays of return water are located in the second baffle chamber after leaving the dry chamber.

The amount of dust captured each day in the dry dust chamber is about thirty to forty tons, while about fifteen tons is captured in the wet baffle chambers.

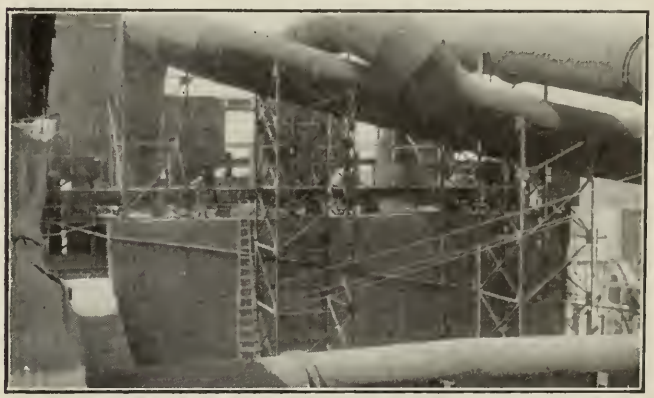


FIG. 5—THE KILN FLUES LEADING TO FANS

The flue at bottom of picture leads from the clay dryer to the dust house.

Where only rotary kilns are operated in connection with the dust collecting system, the proportions of calcium oxide, silica and alumina found in both the dry dust and slurry are found to be such that they can be returned to the kilns without special attention being given to them. Where dust from dryers, such as clay dryers, is also collected in the same system the dust will contain an excess of clay and it must be returned with proper care. At the Colton plant the dust is used so as to balance any irregularities in the composition of the raw mix as it goes to the kiln feed bins.

UTILIZATION OF THE COLLECTED DUST

The method of using the dust will probably be of interest so I will briefly tell you how it is blended.

The rotary kilns and the dust collecting system are in operation twenty-four hours each day, while the clay dryer operates at night long enough to fill the empty clay bins. The slurry from the wet baffle chambers, after being thickened in the tanks, is pumped about every hour over kiln stack bases to a tank holding almost one day's run, and the slurry kept in agitation by compressed air. The hundred spouts under the dry dust chamber are opened daily, only on the day shift,

and the dust conveyed to a bin of almost one days' capacity in the raw grinding department.

The amount of dust deposited in the collector from the kilns is very uniform and from the amount of clay used one day it can be closely estimated how much clay will be deposited in the chamber that night to be mixed with the kiln dust for use the next day and night.

The raw mix, as proportioned at the scales, is made of such composition that the dust must be added to it in order to give a suitable composition. The dry dust can be added to the ground raw mix at any desired speed, and from one to fifteen raw mills can operate without causing inconvenience. When everything is normal, the miller operates the dust feeder at a specified speed for each different number of mills that he may be operating, but in case the raw mix, as tested in the laboratory, is found to require a little more or less clay the laboratory orders the dust feeder to be speeded up or reduced sufficiently to give the desired mixture. As the dry raw mix runs into the kilns, a small stream of the well-mixed slurry from the slurry tank runs by gravity into the kilns.

The dust captured in the dry dust chamber is very fine, practically all passing a No. 200 sieve and about 97 per cent passing a No. 300 sieve. Both this dust and the extremely fine dust captured in the form of

FIG. 6—EXIT WATER

A—Water with load of dust falling from sloping floors into main trough. B—Lateral troughs over settling tanks. C—Surface of water in settling tanks.

slurry have much more sulphur, potasium and sodium than the raw mix, but after a few returns to the kilns they do not show any further increased percentages of these elements.

The water used in the wet baffle chambers very rapidly becomes heavily laden, chiefly with sulphur compounds of potasium, sodium and calcium, and when more than half a pound per cubic foot is found, some of the water is taken out and replaced by fresh water in order not to cause trouble with the sprays. Plans are being made to recover the potash.

The dust which is discharged into the air from the exit to house amounts to about one ton per day. This dust bears no resemblance to the original cement dust, it being for the most part sulphur compounds of potasium, sodium and calcium and about 88 per cent to 94 per cent soluble in water. This dust is produced by the draft drawing out the fine sprays of water from the wet washing system much the same as the wind carries inland the salt-water spray from ocean breakers.

LABOR AND POWER.

The Fleming system requires very little labor. The power consumption is reasonable, not exceeding 2000-kw. hours per day, of which 57 per cent is used on the return water pumps.

The cost of placing the Fleming system in an old plant would depend upon the general layout of the plant, the amount of room available and type of construction. In a new plant the apparatus can be placed with ease and at minimum cost.

In concluding my remarks with the customary contrast of results "before and after using," it is impossible to deal exclusively with the unit used thus far in this paper, as that unit has always operated with the dust collector in connection. Therefore, it will be necessary to take results obtained with one clay dryer and

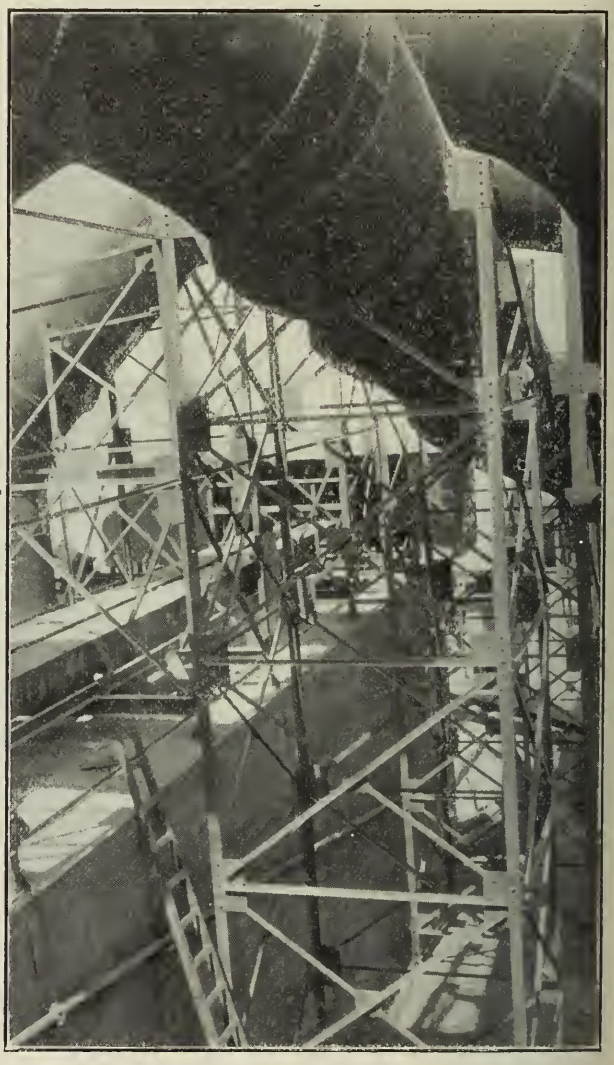


FIG. 7—KILN FLUES

Which first rise from stack base, then come over and slope downward toward the fans.

five kilns, 7½ ft. in diameter and 120 ft. long, which were operated for about 2½ years with normal practice, and then for the same length of time with the Fleming system.

With this dust collecting system in use there was obtained:—(1) About 24 per cent more clinker per barrel of fuel oil consumed; (2) about 5 per cent more clinker produced per hour of kiln operation; (3) about 2 per cent more actual operating time of kilns; (4) over 7 per cent less raw materials required for manufacturing a barrel of cement; (5) the quality of the output was improved; (6) dust from dryers and kilns collected and the nuisance abated.

California Portland Cement Company,
Colton, Cal.

Manufacture of Cream Tartar*

BY OTTO BEST

The history and development of the manufacture of cream tartar and its allied product, tartaric acid (Rochelle salt), in this country is a phenomenal one. Its rise began with the use of cream tartar as a constituent for baking powder, for which, by far, most of the cream tartar is being used.

From a small industry thirty to thirty-five years ago, it has developed in this country to a production of about 1,500,000 to 2,000,000 lb. per month.

It is a general belief that a goodly portion of this product derives its raw material from California, the more so as California produces on an average 35,000,000 to 50,000,000 gal. of wine annually.

However, as a matter of fact, California furnishes only a very small portion of the total used, about 400,000 to 500,000 lb. purity on raw material per year, which is not even one-half the monthly consumption of this country. The rest of the raw materials come mainly from France and Italy, very little from other countries.

RECOVERY OF RAW MATERIAL IN CALIFORNIA

A good many efforts have been made in California to recover more tartrate raw materials. The high-grade goods, argols, are saved completely. The lees, however, are not fully recovered. Most of the large wineries have recovery plants for this product, in which the main stress is laid on the recovery of the alcohol in the lees, the latter being distilled off as brandy.

The lee recovery in this case is, therefore, only incidental and not the main purpose. This is partially due to the low value of the product in comparison to the wine and brandy, and partially on account of the high labor and dirty work in connection with this work. At any rate, the recovery of lees in California is anything but complete.

EXTRACTION OF POMACE

A number of years ago there were several plants in California that aimed at recovery of tartrates from pomace, the residue left after the pressing of the grapes. These plants contributed for a number of years toward the production of tartrate raw material. They disappeared, however, entirely, mainly on account of changed conditions in the industry.

There is no doubt in my mind that with the application of modern means a good deal more tartrate could be recovered in California. The rapid strides of the temperance movement, and adverse legislation, no doubt has a depressing effect on the industry and has greatly stifled the enterprise in this direction.

RAW MATERIAL

The raw material is partly in the form of lees, a product averaging about 35 per cent cream tartar, with varying amounts of calcium tartrate, say 2 to 5 per cent, which is deposited by the first fermentation. It consists of about two-thirds dead yeast, with sulphur, wood chips, etc., and one-third tartrates. This product is, however, mainly used in Europe for the manufacture of tartaric acid.

ARGOLS AND LEES

The raw material in this country for cream tartar is mainly argols, the secondary deposit in the wine barrels after the fermented wine has been drawn off from the settled lees. This product averages about 70 per cent in cream tartar and 5 to 7 per cent in calcium tartrate.

Where gypsum is being used for the removal of some tartrates from wine, much more calcium tartrate is present. Such argols, very high in calcium tartrate, are used for the manufacture of tartaric acid.

The refineries of cream tartar are always connected with the manufacture of tartaric acid, as calcium tartrate and impure mother liquids of cream tartar have to be converted into tartaric acid. At least there is no technical method worked out on an economic basis which would permit reconversion of those impure products into cream tartar.

As the demand for tartaric acid is comparatively small, its manufacture is more or less considered a necessary evil, and its production reduced to a minimum.

There have been a number of processes employed in refining cream tartar.

Neutral Process

One of the earliest in the United States, at least, which appeared, but as early disappeared, was the so-called neutral process. It aimed at neutralization of cream tartar by alkali, and then precipitating again by acid according to the following equations:

$$2KHT + Na_2CO_3 = 2KNaT + CO_2 + H_2O$$

The KNaT was separated from the pulp by filtration, and the solution precipitated as follows:

$$2KNaT + H_2SO_4 = 2KHT + Na_2SO_4$$

About the practical details I know little. No doubt the process failed on account of the costly chemicals used, and technical difficulties.

Settling Process

The so-called *settling* process was successfully used for a number of years and, though rather crude, has decided advantage over the "neutral" process on account of its simplicity and cheapness of operation.

It was used in two modifications, which modifications refer to the working up of the residue into tartaric acid after extraction of most cream tartar.

The crude material was first ground and charged into a large wooden cooking tank, with a perforated copper basket, about 30 in. in diameter, reaching down to the bottom. The heating of the mother liquor to boil was carried out through long copper coils, while the basket was charged with live steam to keep the crude material in suspension.

It was the opinion of the cream tartar manufacturer that this stirring had to be very violent to get all cream tartar in solution. The basket had to "dance," as the official expression was. The wood chips and undissolved cream tartar passed through the holes of the basket and settled outside the basket.

After full charge was made with a solution of from 3 to 3½ per cent, china clay was added in order to make the suspended matter settle faster and more completely. The more china clay, the better, was another axiom of the refiner of the old day.

After settling, the fairly clean solution was drawn off into wooden or, later on, copper crystallizers.

The aim was to get large crystals, in order to be able to remove the mechanical impurities by a washing process, and these large crystals were only obtainable by a low saturation. While full saturation of cream tartar in pure solution is 6.9 g. in 100 c.c. at 100 deg. C., the real strength was rarely over 3.5 g. per 100 c.c.

After cooling, the cold mother liquid was pumped back again to be re-charged, and this process carried on so often until the mother liquor was too impure, and was then sent to the tartaric acid department to be worked into tartaric acid.

*A paper read at the seventh semi-annual meeting of the American Institute of Chemical Engineers, at Berkeley, Cal., Aug. 26, 1915.

WASHING OF FIRST (BROWN) CRYSTALS

The large, brown, cream tartar crystals, with much mechanical impurities, were crushed; that is, the aggregates broken up into large individual crystals, and these stirred up by mechanical devices.

One of these devices was a revolving drum, the so-called *rumbler*. The heavy crystals stayed on the bottom, while the lighter impurities would stay in suspension and could be drawn off from the crystals. The muddy mother liquor was used for tartaric acid manufacture. The crystals, if needed, were washed a second and a third time with mother liquor, until pure.

ACID TREATMENT OF FIRST CRYSTALS

The crystals, thus obtained, contained on an average 90 to 92 per cent cream tartar. The rest was mostly calcium tartrate, a little coloring matter, traces of iron, gypsum at times, etc.

The calcium tartrate cannot be removed by recrystallization, as it is freely soluble in a hot solution of cream tartar, from which it crystallizes or deposits, as cream tartar crystallizes on cooling. It is, therefore, removed by acid. To this interesting reaction I shall come back later on.

This washing with acid was usually combined with the removal of the mechanical impurities, as described before.

After the removal of excess acid by water, the crystals tested 98 to 99 per cent in cream tartar, though the earlier *finished* products averaged only 95 per cent in cream tartar.

REMOVAL OF CALCIUM TARTRATE BY COOKING UNDER PRESSURE

I wish to mention here a process which, for some time, was considered the only commercial process of removing calcium tartrate, and thus getting high-grade cream tartar.

It consisted in dissolving the crystals containing calcium tartrate under about 100 lb. pressure. Under this pressure calcium tartrate, with 4 molecules of crystallization water changes to the anhydrous compound, which is almost insoluble, more so in pure than in impure solutions. Through filtration and crystallization a high-grade cream tartar could be obtained. This process has been entirely abandoned.

RECRYSTALLIZATION

The 98 to 99 per cent product obtained was dissolved again, decolorized with lime-free bone black (bone black treated with hydrochloric acid), china clay added to settle bone black, and the settled solution crystallized in copper crystallizers of considerable size.

The crystals obtained from this solution were washed, dried, and ready for shipment.

The heavier mud from first (brown) cooking tank was charged and leached a second time, while the lighter mud was used as raw material for the manufacture of tartaric acid.

ACID TREATMENT OF MUD

In some factories this mud was treated with sufficient sulphuric acid to decompose all tartrates, bring them in solution, and filter and wash the mud in filter presses.

The clear solution was then neutralized with lime, or carbonate of lime, to precipitate the tartrates as calcium tartrate, an insoluble compound, and remove the potash and other impurities by washing.

DIRECT NEUTRALIZATION OF MUD

In other factories the neutralization was carried out without removing the mud. In this case the reaction takes place in two phases:

$$2KHT + Ca(OH)_2 = CaT + K_2T + H_2O$$
$$K_2T + CaSO_4 = CaT + K_2SO_4$$

If the precipitation is carried out right, the calcium tartrate is granular and heavy, which settles quickly, while the suspended matter settles very slowly. If wash water is drawn off before mud has a chance to settle, soluble and insoluble impurities are removed at the same time.

The process is very simple and avoids the cost of acid and the costly filtration. Yield is also satisfactory, so that the crude settling process has the preference over the acid filtration process.

However the calcium tartrate is obtained, after complete removal of all impurities, it is decomposed by sulphuric acid into gypsum and tartaric acid, the latter worked up as further on explained.

I wish, still, to state that this settling process was, for a number of years, practically the only process carried out successfully on a large scale.

High-Pressure Process of Cream Tartar Extraction

This process was the first attempt of getting the raw material in a filterable state, in order to remove the impurities right from the start, instead of carrying the mechanical impurities all through the process.

There is no doubt that the removal of the impurities from the start is sound in *principle*, though not always possible in practice, without too much sacrifice. Let us see how this process attempted the solution of the problem:

Argols or lees were ground and cooked under about 100 lb. pressure for about two hours. Through this cooking, all albumin and other constituents detrimental to filtration, were destroyed. At any rate, the solution, after this treatment, was filterable.

The clear solution, after filtration, was run into crystallizers and crystallized and otherwise treated as described, with this difference that mechanical impurities were removed by filtration and need not be removed by a "rumbler."

This process was mainly used for low-grade goods, lees. From a technical and mechanical standpoint it works well. However, the loss on raw material is very large, particularly in presence of calcium tartrate.

Systematic investigations have shown that the loss on cream tartar was in direct proportion to the amount of calcium tartrate present. The latter seems to decompose more readily than cream tartar. The lime forms fresh calcium tartrate, which again is decomposed, etc.

A further drawback of this process is that the mother liquors become very soon discolored and syrupy and have to be discarded.

Last, but not least, a pressure process, especially with an acid product, is never a desirable process technically. For these and other reasons it is to-day practically abandoned. It is interesting from a historical standpoint, mainly because it introduced filtration, and with it modern methods in the manufacture of cream tartar.

Roasting Process of Extracting Cream Tartar

We now come to the latest process, the so-called "roasting process."

Argols or lees are roasted at a temperature above the decomposition point of albumin, organic coloring matter, etc., but below the decomposition point of cream tartar and calcium tartrate. This temperature is around 150 deg. C.

The effect of this roasting is marvelous. While argols and lees, when extracted without roasting, are practically unfilterable, just a few dark-colored drops passing through the filter, after roasting the solution passes the filter almost like water, the filtered solution is absolutely clear, and of light straw yellow color.

The roasting is, therefore, not only for the purpose of an increased filtration, but is a great purifying process as well. The mother liquors from the roasted goods can be used over again much longer than from unroasted goods.

DIFFERENCE OF ROASTING AND HIGH-PRESSURE PROCESS

You will note the big difference between the two processes which aimed at filtering: The first process, cooking under pressure, increases the coloring and extract matter going into the mother liquors, and causes big losses on tartrates, besides larger technical difficulties.

The second process, dry roasting, improves the mother liquors by decreasing extract and coloring matter, is carried out *without any loss* on tartrates (I refer here to losses due to this roasting), as experiments on a small and large scale and operations on a technical scale for years have conclusively proven. It is, furthermore, simple and efficient.

After roasting, the raw material is ground coarsely and extracted in wooden vessels with agitators. Boiling is avoided. The charge is now filtered through bronze filter presses into copper crystallizers, and allowed to crystallize for four to five days. The filtration is very rapid.

With a pressure not to exceed 50 to 60 lb., 24,000 gal. could easily be filtered within about three hours without cleaning filter press. Whoever has tried to filter cream tartar will appreciate the technical success of this process.

The amount of filter cloth used was very low. With a monthly production of about 150,000 lb. cream tartar, the bill for filter cloth for this department was below $100.

As the labor and other items in connection with the roasting process and filtration are also low, and the yield on cream tartar much higher, than with the other processes, the roasting process must be considered the only rational and modern process.

COMPLETE EXTRACTION OF MUD WITHOUT ACID

The leached out mud is extracted a second and a third time with cream tartar mother liquor in a systematic way, and is then practically free from tartrates. It is not necessary to give this residual mud an acid treatment, or send it to the acid department. It is sufficiently low in tartrates to be discharged. It still contains some phosphates, nitrogen, potash, and can, therefore, be dried and used as a filler for fertilizer.

Another great advantage of this process is that the saturation of the solution can be much higher than with the settling process. The saturation can be brought up to 6 per cent (with the settling process about 3½ per cent), as we need not to settle nor depend on large crystals, as the cream tartar crystals are free from mechanical impurities. This, naturally, cheapens installation and manufacture.

FIRST (OR BROWN) CRYSTALS FROM ROASTING PROCESS

The brown crystals test about 90 to 92 per cent in cream tartar. The rest is calcium tartrate, as mentioned in the description of the previous process. The calcium tartrate crystals are usually yellow, and adhere to the edges and corners of the cream tartar crystals, as they crystallize out *after* the cream tartar is practically crystallized out.

They can clearly be distinguished from one another, as the cream tartar crystals have sharp edges and corners and are transparent, while the calcium tartrate crystals look amorphous, are not transparent, and are usually uniformly colored through a trace of iron. If free of iron they are white, but not transparent.

REMOVAL OF CALCIUM TARTRATE FROM RED CRYSTALS

On account of this property, that the calcium tartrate crystals stick to the surface of the cream tartar crystals (do not permeate the cream tartar crystals throughout), they can be dissolved in acid without fine grinding of cream tartar. The cream tartar crystals are merely crushed into individual crystals, and then treated with acid. These reactions in this connection are very interesting, as one (the first one) is reversible. Here are the reactions:

$$KHT + HCl \leftrightarrows KCl + H_2T$$
$$CaT + 2HCl = CaCl_2 + H_2T$$

The first reaction is reversible, for the reason that cream tartar is almost insoluble in KCl solution. The solubility of pure cream tartar in a 10 per cent KCl solution is 0.04 g. cream tartar in 100 c.c. The stronger the KCl, the greater the tendency of forming cream tartar back again. In reacting back, free hydrochloric acid is formed, which is capable of dissolving calcium tartrate. Thus the free hydrochloric acid is neutralized and more KCl can act on H_2T and form cream tartar and HCl. The hydrochloric acid again acts on the calcium tartrate, etc., etc.

PURITY OF ACID-TREATED CREAM TARTAR CRYSTALS AND LOSS ON CREAM TARTAR TO TARTARIC ACID

As stated, the reverse action takes place the more, the stronger the solution. For this reason I add strong hydrochloric acid, 20 to 22 deg. Bé to the fairly dry cream tartar, just enough to cover it. This is about equal in weight with the calcium tartrate.

Investigations showed that in the first twenty-four hours the purity was raised usually to about 95 per cent, while the mother liquor contained about 2 parts of cream tartar to 1 part of calcium tartrate (figured as calcium tartrate).

After forty-eight hours the purity would rise to 97.5 to 98 per cent purity, while the mother liquor contained about 1 part of cream tartar to 1 part of calcium tartrate in solution.

After seventy-two hours the purity of the cream tartar was usually 99 per cent, or above, and the mother liquor contained now about 1 part cream tartar and 2 parts calcium tartrate.

These are average figures from practice, and change according to concentration of hydrochloric acid and temperature; but mainly with the size of calcium tartrate, which varies considerably.

As will be seen, time is the essential factor of this reaction.

These figures were obtained when no agitation or stirring was applied.

Comparative figures, under vigorous stirring for a comparatively short time, say one-half to one hour, demonstrated that the amount of cream tartar in solution and the amount of hydrochloric acid were both much larger in the latter than in the former case.

In a previous chapter I mentioned that the manufacture of tartaric acid in this country was, more or less, considered a necessary evil. Since the hydrochloric acid solution of tartrates can only be worked into tartaric acid, it is important that as little as possible of the cream tartar is dissolved by the hydrochloric acid. Long standing with hydrochloric acid dissolves comparatively little cream tartar.

More cream tartar can be precipitated from this hydrochloric acid solution by partial neutralization of the excess hydrochloric acid.

The brown cream tartar crystals thus treated with hydrochloric acid are washed with water, and test now over 99 per cent in cream tartar.

RECRYSTALLIZATION AND DECOLORIZATION

They are redissolved, decolorized with boneblack, filtered and crystallized a second time, washed, dried, and are now colorless crystals of over 99.5 per cent in cream tartar.

When the white mother liquor does not furnish pure crystals any longer, it is discharged into the red batches. A corresponding amount of red cream tartar liquor is discharged into the tartaric acid department.

LOSS IN MANUFACTURE

The loss in manufacture of cream tartar is comparatively small, as all the impure products which cause the loss are discharged into the tartaric acid department.

This transfers the difficulties and losses merely from one department to the other.

The loss in the cream tartar manufacture are partially due to fermentation, which loss is very low, practically nil, with the roasting process; larger with the other processes.

FERMENTATION OF CRUDE MATERIAL

The fermentation may start with the raw material, stored away, when the same had not been completely dried. In order to establish this loss, a cream tartar test (Klein test) is made from the raw material and a potash determination, and the latter figured into cream tartar. If this figure is higher than the direct determination, loss through fermentation of raw material has occurred.

LOSS THROUGH COOKING

Some loss is due to cooking, possibly a little through roasting, though a direct determination never disclosed a loss in either direction.

There is no further source of loss, outside of some mechanical loss.

Manufacture of Tartaric Acid

We now come to the manufacture of tartaric acid. As indicated above, all products of cream tartar manufacture too impure for cream tartar are transferred to the tartaric department.

The various sources are: impure cream tartar, mother liquor, and the tartrates from the hydrochloric acid treatment. No mud need be treated in the roasting process, as the extraction in the cream tartar department is complete.

MANUFACTURE OF CALCIUM TARTRATE

These products are transformed into calcium tartrate, an insoluble compound, which can be washed for the removal of the impurities.

If we manufacture calcium tartrate from cream tartar crude material, two steps are needed, as explained before. These products, with excess hydrochloric acid, form enough $CaCl_2$ to precipitate the neutral tartrates as calcium tartrate without further addition of gypsum.

SOLUBILITY OF CALCIUM TARTRATE

The solubility of pure calcium tartrate is about 1 part in 6000 parts of cold water. This solubility is raised to 1 in 500 parts in *hot* water. It is well, therefore, to neutralize cold, if large losses are to be avoided.

Impurities in solution affect the solubility of calcium tartrate. $CaCl_2$ and KCl *decrease* the solubility of calcium tartrate. All other impurities seem to *increase* the solubility of calcium tartrate. Organic substances in solution, for instance, considerably increase its solubility; so do iron and aluminum salts, phosphates, sulphates, etc. This is the main reason why the loss in manufacture is transferred from cream tartar to tartaric acid.

PROPORTION OF CREAM TARTAR TO TARTARIC ACID

Usually only about 10 per cent of the production of cream tartar is obtained for tartaric acid manufacture, and by skillful manipulation it can be kept much lower. Correspondingly, the impurities in the tartaric acid department are increased. It needs very careful operation and full control of all operations to keep the loss down.

LOSS THROUGH PRECIPITATION AS CALCIUM TARTRATE

This precipitation entails the biggest loss of any individual step. It needs, therefore, the most attention and study. It also needs full attention, as in this step the impurities are removed, and if fully removed will make subsequent steps easier and losses smaller.

The neutralization was carried out by some manufacturers with lime, but most manufacturers use now carbonate of lime. After neutralization, the calcium tartrate is washed by decantation until all impurities are removed. This has to be done swiftly, as otherwise calcium tartrate will ferment and cause loss.

EVAPORATION OF TARTARIC ACID

The pure calcium tartrate is decomposed with a very small excess of H_2SO_4 evaporated at low temperature, say not to exceed 170 deg. Fahr., usually at first in open evaporators, then in vacuo, until saturated hot, and then run into crystallizers. The cooled-off mother liquor is evaporated a second, third, etc., time, as long as it still forms good crystals. Last impure liquor is reprecipitated.

All crystals are washed, dissolved, decolorized, filtered, evaporated and again crystallized to form commercial tartaric acid.

If evaporation is carried out in open vessels, the temperature has to be controlled carefully, otherwise large losses on tartaric acid will be incurred.

META-TARTARIC ACID

Another source of loss is due to the formation of meta-tartaric acid. This acid is formed through evaporation in open vessels, especially in presence of impurities. It is supposed to be a semi-anhydride of tartaric acid, non-crystallizable, with calcium and acid potassium salts much more soluble than the ordinary tartrates.

If present in larger quantities, tartaric acid will not crystallize, though evaporated much above the saturation point of tartaric acid.

Reprecipitating cold with lime or calcium carbonate will entail a large loss on account of the higher solubility of the calcium meta-tartrate over the ordinary tartrate of lime. When this calcium meta-tartrate is heated to boil, it is changed back to the ordinary calcium tartrate, and after decomposition with sulphuric acid will give crystallized tartaric acid again.

In a well regulated factory with vacuum evaporators, meta-tartaric acid will not be found.

A number of years ago I worked out an approximate determination of meta-tartaric acid. I did not follow it up for the reason that I prevented its formation.

The brown tartaric acid, as it comes from the crystallizers, is washed, dissolved in water, decolorized, evaporated in vacuo to saturation hot, crystals taken out after five or six days' standing, washed, dried, screened. and are now ready for shipment.

The mother liquor is evaporated a second and third time, as long as good crystals are obtained, and the last white mother liquor returned to the first brown.

REPRECIPITATION OF TARTARIC ACID AS CREAM TARTAR

There used to be a process of working up the last brown tartaric acid in order to recover cream tartar and to remove the impurities at the same time. This mother liquor, which contains many impurities and free sul-

phuric acid, was diluted, and the free sulphuric acid neutralized by lime. The gypsum formed was filtered off, and the remaining clear solution treated with excess KCl.

The reactions taking place were as follows:

$$H_2T + KCl = KHT + HCl$$

Considerable hydrochloric acid is being formed, when about 5 per cent KCl is in excess.

But there are impurities present, such as Fe, Al, K, etc., which will combine with the free acid and make precipitation more complete, while the metals stay in solution as chlorides, and are removed as such.

I give the following reaction as an illustration:

$$Al_2T_3 + 3KCl + 3HCl = 3KHT + 2AlCl_3$$

The two reactions are, of course, simultaneous.

This process, I believe, is abandoned, as it was too expensive on account of the costly potash salts used, and the large loss on tartrates. However, it was one practical attempt to revert tartaric acid into cream tartar, at the same time removing the impurities.

OTHER PROCESSES OF TARTARIC ACID MANUFACTURE

I wish to state that where tartaric acid is manufactured, not as a by-product of cream tartar manufacture but as the main or only product, as in many European countries, a number of processes are known for the manufacture of tartaric acid. These processes, however, are outside the scope of this paper, as we are in the first case interested in the industries as they were called into existence in this country through economic conditions.

REFINING IN ONE OPERATION, OR CRYSTALLIZATION

In general, I want to stay that some attempt has been made, both in cream tartar and tartaric acid manufacture, to refine these products in *one* crystallization, and I myself have carried out many experiments, without, however, having gone beyond the laboratory scale. Short cuts of this kind are very tempting, because of the shortening of the process and consequent smaller investment and cheaper productions. Such attempts have been successful in other branches of manufacture, like boracic acid, borax, etc. But to the best of my knowledge no such process has successfully been carried out in the manufacture of cream tartar and tartaric acid in this country.

In France, I was informed, a process was introduced on the line of the *neutral* process, which claims pure cream tartar in one operation. How successful it is technically, I cannot tell.

To reiterate: Of all processes advocated and carried out in America, the only survivor seems to be the "roasting process," which, in some form or other, is practically carried out in every large cream tartar refinery in this country. It is rational, because it removes the impurities, and with it the trouble *from the start;* it permits the introduction of modern filtering apparatus and appliances, without being too costly, to offset these advantages. It is a clean process from beginning to end, easily and fully controllable.

It gives high yield and rather *avoids*, than cures, trouble and disease.

These, in my mind, are the chief characteristics of a modern process, of which the "roasting process," in connection with cream tartar manufacture, is an example.

San Francisco, Cal.

The California Slime Extraction Company, of Setter Creek, California, is installing a 5 by 10 ft. adjustable quick-discharge tube mill of Chalmers & Williams, of Chicago Heights.

Gold Milling in California—A Comparison

BY LEROY A. PALMER

Practice at the various mills in the Gold Belt of California presents a striking uniformity. The first mills used only amalgamating plates. Then the vanner came into use to treat the tailings which frequently carry a large portion of the values in connection with iron sulphides or "sulphurets," which name still clings in this country. Usually the vanners treated the pulp without any previous classification. Chlorination and, later, cyanide plants have been installed for the manufacture of bullion from the concentrates. During the past three years there has been a departure from standard practice on the part of two companies which have constructed and are operating all-sliming cyanide plants. These mills, the Globe Consolidated at Dedrick, Trinity County, and the Black Oak, at Soulsbyville, Tuolumne County, are the only ones treating gold ores in which amalgamation does not form the first step in the treatment.

This clinging to methods that have become obsolete in many other districts does not indicate lack of progress on the part of California millmen. Most of the ores, especially of the Mother Lode, are readily susceptible to this simple treatment and elaborate refinements would not yield such an increase in saving as would justify the additional expense. For this reason progress along the line of ore treatment in this district has been mechanical rather than metallurgical. The Mother Lode ores have the larger portion of their values in the free state, and every mill in this district depends on plates for the greater portion of its recovery. But as one leaves the Mother Lode proper and goes to one of the adjoining districts, such as the East Belt, he finds many mines at which the free values are in much smaller proportion and the treatment of the sulphides becomes more complex although the general similarity of the ores still obtains.

Two of the new mills in the Gold Belt are the Plymouth Consolidated, at Plymouth, Amador County, on the Mother Lode proper, and the Black Oak, at Soulsbyville, Tuolumne County, on the East Belt. They present an interesting comparison, as aside from the fact that each uses batteries for primary crushing, they have not a single point in common, although they are treating ores not greatly dissimilar. Yet each one is undoubtedly well chosen to meet the particular conditions under which it operates.

Plymouth Consolidated Mill

The Plymouth Consolidated mill, which commenced operation in August, 1914, represents the latest stage in the development of standard milling practice in the Mother Lode district. The Plymouth ore is typical of the "stringer leads" of this belt, consisting of alternating bands of quartz and slate, with considerable clay. The gold occurs free and in connection with "sulphurets," which are principally pyrite and arsenopyrite.

Crushing and Conveying

The ore is hoisted from a two-compartment and manway shaft in automatic dump skips and discharged to a small bin of 125 tons capacity. From this bin it is fed through a hand-operated sector gate to a 5K Gates crusher driven by a 35-hp. motor. It is of a friable nature, and consequently breaks in the stopes with a large proportion of fines, and the coarser chunks contain a considerable amount of clayey matter.

On this account it was found that the usual practice of separating the coarse and fine over a grizzly would result in an irregular feed to the conveyor. To obviate this the entire run of mine is sent through the

crusher, which is kept buried under ore and acts as a feeder to the conveyor to the mill bins. This method provides the conveyor with a regular feed without overloading, as would be the case if a grizzly were used, and when there would be times when practically all of the ore would pass through it to the belt and little or none would go to the crusher.

The Plymouth shaft is located in a flat so that it is impossible to deliver the ore to the top of the mill without a considerable elevation. The crusher is set below the level of the ground and discharges to an 18-in. "Lamina" rubber belt conveyor, the housing of which is shown at the left of the illustration (Fig. 1). This conveyor has a lift of 108 ft. and a horizontal length of 631 ft. It is driven in two sections, one 350 ft. and one 310 ft. long on the slope, with 10 and 15-hp. motors respectively. The inclination of the belt varies, but, as can be seen by referring to the illustration, the greater part of the lift comes on the second section, hence the necessity of a larger motor for the shorter belt. This portion of the conveyor attains a slope of 21° 30′, corresponding to that of the roof of the mill, and very nearly equal to the maximum on which these ores may be conveyed without rolling or sliding. The inclined belt discharges to a horizontal belt 85 ft. long driven by a 10-hp. motor and carrying a tripper by which the ore is distributed in the bin at any desired point. Link-belt equipment is used throughout the conveyor system. After handling approximately 110,000 tons of ore in eleven months, the rubber belts in this system show practically no wear, a strong argument in favor of the economy of the best class of equipment.

FIG. 1—PLYMOUTH CONSOLIDATED MILL

Fine Crushing and Grinding

The mill is of timber frame construction, with corrugated iron sides and roofing. As the illustration shows, it is well supplied with windows and skylights. It is well lighted at night by numerous large tungsten lamps. The floors are of concrete. The ore bins, which have a capacity of 1200 tons, are of heavy timber with flat bottoms. They are so proportioned that about 30 per cent of the ore, practically a day's run, will discharge from them by gravity, leaving a reserve supply of 840 tons which can be shoveled out in case of emergency. This is somewhat more than necessary to keep the mill running two days, 380 tons being the standard operating capacity.

The mill bins discharge by means of Challenge feeders driven from the stamp stems to thirty stamps arranged in six batteries of five each. Only five batteries are used at a time, except as noted later. The mortars are set on heavy concrete piers tied with crossed bolts. This gives a very satisfactory foundation and the batteries are practically free from vibration. The weight of the stamps used on Mother Lode ores has been gradually increased from time to time, and those at the Plymouth, weighing 1250 lb., are the heaviest yet installed, although they have a close second in the Black Oak to be mentioned later. The dies are set for a discharge from 5½ to 6½ in., the end dies being set ½ in. higher than the others. The tappets are set to give a drop of 7 in. and are allowed to wear to 7½ before taken up. The speed is 100 drops per minute, and the order 1-3-5-2-4. A 100-hp. motor drives the batteries.

The batteries crush through a six-mesh screen (No. 60 Rektang), which gives a free opening of 0.087 in. The pulp is collected in two launders, one to each fifteen stamps. These launders, unite, but after passing a sampler divide again and each goes to two classifiers in series. The first classifier is merely an inverted wooden pyramid measuring 20 in. on the upper edge, and the second is a 36 in. steel cone. These classifiers, so called, are in reality "sloughing off" devices, no counter current of water under pressure being employed and the separation being the result of the difference in the rate of settling of the various particles. The underflow of both classifiers of a series goes to the feed end of an 8-ft. by 22-in. Hardinge mill and the overflow is laundered to the discharge end of the mill. The

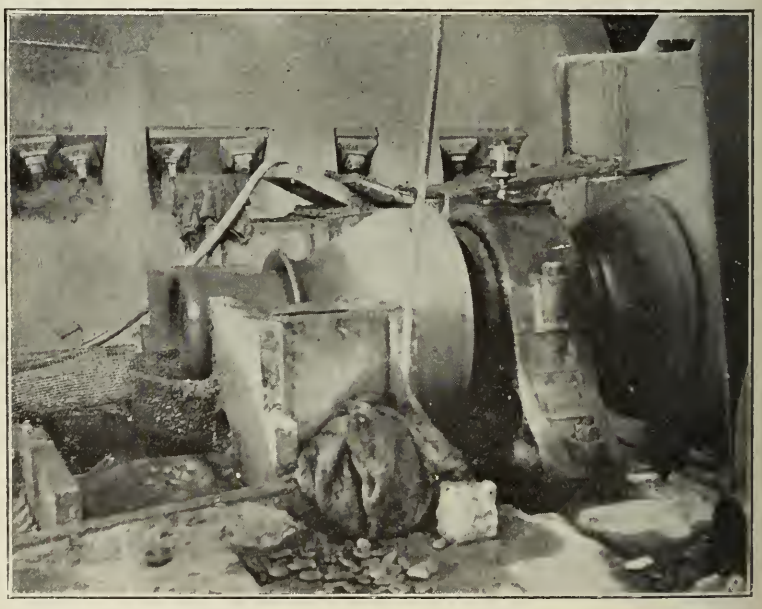


FIG. 2—HARDINGE AMALGAMATOR, PLYMOUTH MILL

slate in the ore is pretty well pulverized in the process of stamping, so that most of it overflows from the classifiers and the principal feed of the mills is pure quartz.

The mills have been watched closely and several tests made to determine the capacity and consistency of the pulp at which they would develop their highest efficiency. The dilutions of pulp tried were from 1 solid to from 0.666 to 0.950 water and various rates of feeding were tried out. As a result of these experiments it was found that the mill does its best work at a capacity of 140 tons per twenty-four hours with a pulp consisting of 1 part solid to from 0.70 to 0.75 water (Sp. Gr. 1.76-1.79).

An old hoist motor rated at 200 hp. is used to drive the tube mills, elevators and concentrating tables. This motor is very much larger than is actually required, as it is estimated that the power consumed by each tube mill is only 40 hp. Following is an average of the screen analyses of feed and discharge over a considerable period.

Size	Feed	Discharge
+ 20	30.0-40.0	0.5- 1.8
+ 30	20.0-25.0	5.5- 9.0
+ 40	11.0-13.0	10.0-13.0
+ 60	12.0-16.0	23.0-26.0
+ 80	4.5- 7.5	12.0-15.0
+100	2.5- 4.0	7.0-10.0
+200	3.0- 4.0	10.0-14.0
—200	3.0- 4.0	15.0-20.0

The minus 200 discharge of the mill was tested for sands and colloids by diluting with a large proportion of water, agitating and decanting all solids that would not settle within two minutes after agitation ceased. The process was repeated five or six times, and it was assumed that such solids as remained after the last decantation were in granular form and that all of the slime had been removed. According to these tests only 5 or 6 per cent of the discharge of the Hardinge mills is in the form of slime.

Danish pebbles are used in the mills with a consumption of 1½ lb. per ton of ore when the best grade of pebbles can be obtained. Local pebbles were tried and given a fair test, but it was found that their consumption was 6 to 7 lb. per ton of feed, and that the difference in cost was not sufficient to offset the difference in the amount used.

Amalgamation

Fifty-five to 70 per cent of the gold in the Plymouth ore is free. Forty per cent of the free gold is in flakes of appreciable size, greater than 1/64 in. in diameter. This makes it advisable to practise amalgamation in two stages, as any attempt to catch all of the gold, both coarse and fine, on one set of plates would result in an inordinate amount going into the plate tailings and thence into the concentrates. This is a result to be avoided if possible, as the smelter does not pay full value for the gold recovered from that source, and there is the further possibility of loss in the table tailings. Standard Mother Lode practice has been disregarded in that no attempt has been made to amalgamate in the batteries, although amalgamation in the Hardinge mills was tried when operations were first commenced. This was successful so far as the actual recovery of the gold was concerned, but was attended by a rather high loss of quicksilver and much inconvenience in cleaning up, and consequently was discontinued.

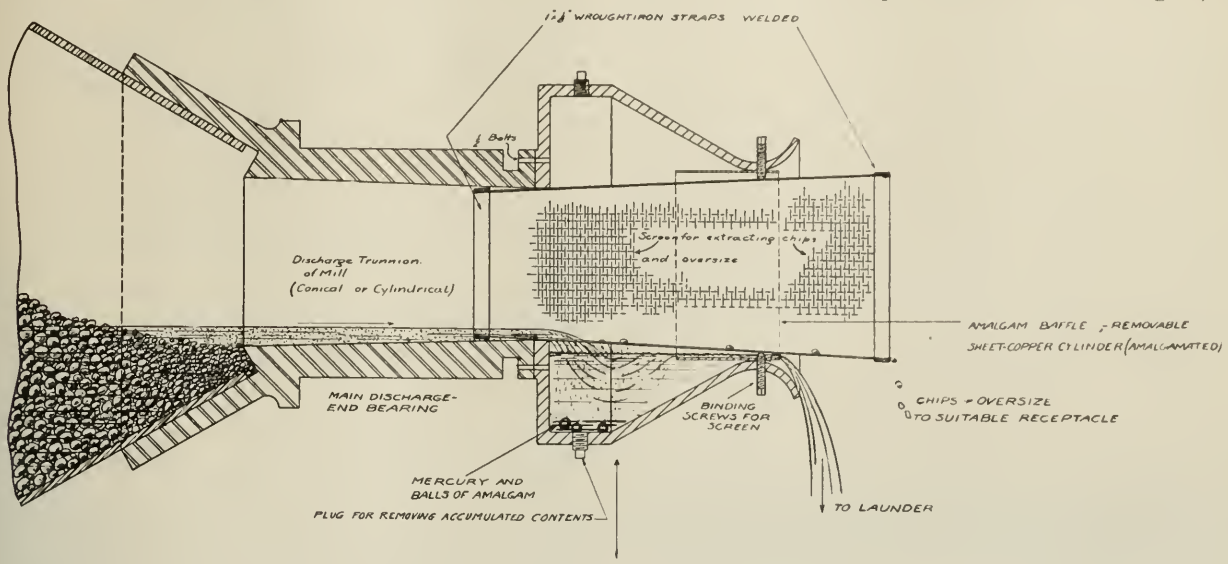

1½" WROUGHT-IRON STRAPS WELDED
¾ Bolts
Discharge Trunnion of Mill (Conical or Cylindrical)
Screen for extracting chips and oversize
AMALGAM BAFFLE - REMOVABLE SHEET-COPPER CYLINDER (AMALGAMATED)
MAIN DISCHARGE-END BEARING
BINDING SCREWS FOR SCREEN
CHIPS = OVERSIZE TO SUITABLE RECEPTACLE
MERCURY AND BALLS OF AMALGAM
PLUG FOR REMOVING ACCUMULATED CONTENTS
TO LAUNDER
HARDINGE AMALGAMATOR
PATENT APPLIED FOR

FIG. 2a—DIAGRAM OF HARDINGE AMALGAMATOR

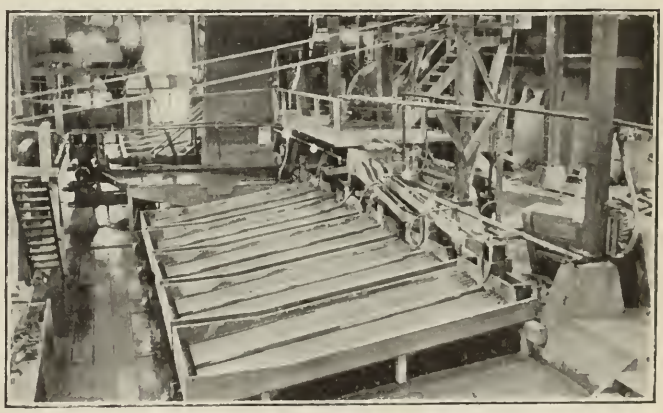


FIG. 3—TABLE PLATES AND WILFLEY TABLES, PLYMOUTH MILL

The next move was to attach a Hardinge amalgamator to one of the mills and a Plymouth amalgamator, to be described later, to the other. These have given very satisfactory service. The Hardinge amalgamator, Fig. 2, may be described as a miniature Hardinge mill which is attached to the discharge of the mill proper. It is of cast iron, and the object is to produce the same effect in amalgamation as the mill does; that is, to bring the

gold, especially that which is rusty or in coarse particles, into forceful contact with the quicksilver. The amalgamator gives the pulp a rolling action as it is discharged through it, and when it is run dry the discharge cone becomes coated with amalgam and balls of the latter form having diameters up to ¾ in. These balls materially assist in the amalgamation and at cleanup a few copper balls are put into the amalgamator for the same purpose.

After passing the Hardinge amalgamator the pulp is run over a 4-millimeter screen shown in the illustration for the purpose of removing chips and any small pebbles that may have been thrown out. Thence it runs over two silvered sluice plates, each 2½ ft. by 6 ft. on a grade of 2 in. per foot and through a launder to ten table plates (Fig. 3), each 3 ft. by 14 ft., set in pairs on a grade of 2½ in. per foot. Shallow traps are provided at the top, middle and bottom of the sluice plates and top and bottom of the table plates. The tailings from the table plates go to an elevator.

The above describes the process of primary amalgamation as carried on in one section of the mill. Practice in the other section differs slightly. Here the Hardinge mill discharge passes directly over the sluice plates and thence to a Plymouth amalgamator, Fig. 4. This amalgamator was designed and built in the Plymouth mill and has proved very successful. It is now in use at the Argonaut mill at Jackson, Col., and on one of the Natomas Consolidated gold dredges. It is a wooden box 6 ft. by 18 in. divided lengthwise into two compartments, one 12 in. and the other 6 in. wide. It receives 200 2-in. longitudinal strokes per minute, being actuated by the head motion of an Isbell vanner. The wider compartment has an iron bottom and is covered to a depth of ¼ in with quicksilver. The narrower compartment is provided with a regular amalgamating plate in the bottom. The pulp from the sluice plates passes to the wider compartment of this shaking amalgamator, where it is subjected to a rapid agitation in the quicksilver bath and then discharged over the plate in the second compartment to the table plates. This device is, in effect, a shaking amalgam trap for the recovery of the coarse gold. Before the installation of the Hardinge and Plymouth amalgamators free gold could be seen in the concentrates of the Wilfley tables, but these devices have remedied that trouble.

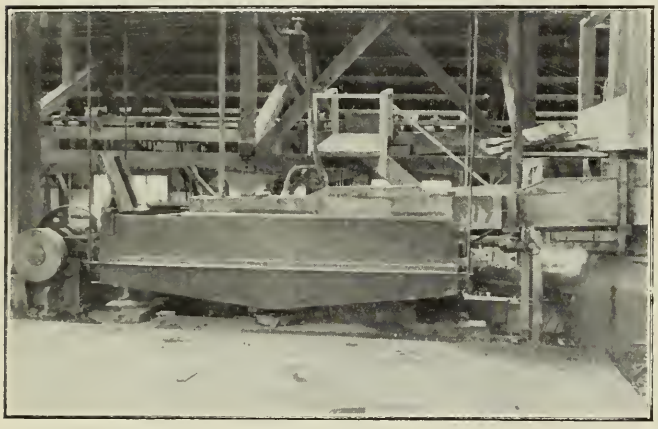


FIG. 4—PLYMOUTH AMALGAMATOR

The amalgamators, traps on the sluice plates, sluice plates and traps at the heads of the table plates are cleaned up daily. The table plates are cleaned twice a month. It is found that of the free gold recovered in the form of amalgam 53½ per cent is caught in the amalgamators and traps. Of the remaining 46½ per cent, 85 per cent, or 40 per cent of the total recovery, is caught on the sluice plates following the Hardinge mills and 6½ per cent of the total is caught on the table plates. Thus it will be seen that it is a distinct advantage with this ore to amalgamate in stages.

The amalgam from the amalgamators and traps retorts 50 to 60 per cent sponge; from the sluice plates, 35 to 45 per cent, and from the table plates, 20 to 25 per cent. The combined amalgam from all sources retorts from 42½ to 47 per cent, which is considerably higher than the 30 to 40 per cent which MacFarren gives as the average amount of sponge.

Concentration

All tailings from the table plates are run to an elevator with 15-in. belt, 26-ft. lift and a speed of 450 ft. per minute. As elevators are prone to give more or less trouble two have been installed at this plant at this point. One is run for a week, then shut down and given a thorough overhauling, while the other is used. These elevators are belt-driven to avoid any gear trouble. The boots are so set as to be readily accessible, with large doors so that if one does choke down practically all of the ore overflowed in the boot will run out by gravity when the door is opened. With these precautions no trouble has been experienced in their operation, and after eleven months of continuous work the belts show no appreciable signs of wear.

The elevator discharges to a 66-in. Callow cone, the underflow of which goes to a two-compartment Richards hindered-settling classifier. Each compartment of the classifier feeds a No. 6 Wilfley table, shown in the background of Fig. 3, that makes 245 ⅝-in. strokes per minute, producing tailings and concentrates but no middlings. The Wilfley concentrates contain about 11 per cent arsenic. They make up one-third of the tonnage product of the mill and three-fifths of its value.

FIG. 5—CLEAN-UP JIG, PLYMOUTH MILL

The tailings of the Wilfley tables are laundered to an 8-in. elevator, which raises them 22 ft. with a speed of 450 ft. per minute to two pyramidal settlers. The underflow of each settler returns to a Hardinge mill and the overflow is run to the tailrace and wasted.

The Wilfley tables are placed on the same level as the table plates. On the next level, which is the lowest, are the vanners, thirty of Isbell design, with 6-ft. belts making 195 1-in. strokes per minute. The Isbell machine was chosen because it makes a satisfactory grade of concentrates and the cost of upkeep is less than that of most of the other designs of vanners.

The overflow of the Callow cone which receives the pulp from the first elevator is laundered to two dis-

tributing tubs. Each of these tubs distributes to three other tubs, each of which feeds four vanners, twenty-four vanners taking the Callow overflow. The overflow of the Richards classifier is laundered to two distributing tubs, each of which feeds three vanners.

All concentrates, both table and vanner, discharge to tubs from which they are shoveled and, after drying, are sacked and shipped to the smelter at Selby for treatment. Sweepings and overflow from the concentrate boxes are led to a sump and shipped. When the mill is run at its full capacity, 380 tons a day, the output of concentrates is from 5 to 7½ tons, a concentration ratio of from 50 to 75 into one.

Cleanup and Sampling

Instead of using the usual clean-up barrel and pan, the sands from the plates and the daily traps are treated in a "clean-up jig" designed at this plant and illustrated in Fig. 5. This jig has vertical sides and the general

FIG. 6--BLACK OAK MILL

appearance of a large Calumet classifier. It receives 210 2-in. longitudinal strokes per minute from an eccentric without differential motion. The sands are fed in at the top over a ¼-in. screen, from which they pass over a baffle and are subjected to the agitation caused by the eccentric, which results in a stratification so that the sands overflow at the discharge and the amalgam settles to the bottom of the jig, where it may be tapped off at the plug shown. The jig concentrate is treated in a 2-ft. clean-up pan.

Sampling is done by automatic samplers. One sample is taken of battery pulp by taking a cut the full width of the launder below the batteries. This sample is further cut down by split samplers so as to give an average of the shift's run. Tailings are similarly sampled. A sample is also taken at thirty-minute intervals from the distributor to the battery bins. These samples will usually check the pulp samples from the battery with a maximum error of 10 cents per ton. Assays of talings and concentrates are posted daily for the information of the millmen. The extraction will run 90 per cent on an ore assaying $5 per ton or better. On lower grade ore it will be a little less.

The mill is handled by two men on each shift actually engaged in operation. These are an amalgamator, who also looks after the crushing machinery and who acts as foreman on the night shifts, and a vannerman. In addition the day shift has a foreman, repairmen, amalgamator helper and concentrate sacker. Crushing is done entirely on the night shift. Detailed costs of milling are not available at present, but the management states that the total costs of mining and milling, including new construction, development, etc., are from $2.70 to $3 per ton.

The Plymouth mill was designed with the idea of treating this ore as efficiently as possible, and it has been part of this general scheme to surround the operators with such conditions as would tend to promote their efficiency. Mention has been made of the lighting system. Heat is furnished in cold weather by numerous electric heaters. As the general location hereabouts is somewhat conducive to malaria all drinking water used in the mill is filtered. There is a change room in the mill supplied with hot and cold water and, shower baths are available at the main change house at the shaft. Motors are placed, as far as possible, out of the way, and all line shafts are readily accessible from broad runways. But best of all, and a feature that cannot be commended too highly, there is not a motor, belt or gear in the mill that is not so carefully protected but that a man could only be caught in it by deliberate intent on his part.

Horsepower

As stated, a larger motor than necessary is used for the Hardinge mills, elevators and tables. In the following summary the actual horsepower used on these machines is estimated with a liberal allowance for transmission and friction losses in a rather extensive system of line shafting.

Machine	Horsepower
Crusher	35
First conveyor	10
Second conveyor	15
Third conveyor	10
Stamps (twenty-five)	85
Hardinge mills (two)	80
Plymouth amalgamator	1
Elevators (two)	10
Wilfley tables (two)	3
Vanners (thirty)	25
Total	274

This equals an actual expenditure of about 0.7 hp. per ton of ore treated. Power is purchased from the Pacific

FIG. 7—CAM FLOOR BLACK OAK MILL

Gas & Electric Company at 44,000 volts, transformed at the mill and distributed at 440 volts.

Modified Practice

Under certain conditions the system described above is modified to some extent. When both Hardinge mills are used only twenty-five stamps are dropped, but if the grade of ore is low, or if a mill needs lining, one of them is cut out and all thirty stamps are dropped, three of the batteries being equipped with No. 296 Rektang

(19-mesh) screen. With the finer screen stamp duty per twenty-four hours is from 8½ to 9½ tons. This compares with 12½ to 16 tons through the 6-mesh screen according to the amount of hard quartz in the ore. Screen tests of the battery discharge through the 19-mesh screen show about the same percentage of +30 material in the pulp as from the Hardinge mill, but that the colloids will run 21-22 per cent. From the above it appears that forty-two stamps would be required to crush direct the same amount now handled by the twenty-five stamps and the two Hardinge mills.

Concentrate treatment has always been an important question in the handling of Mother Lode ores. At present the Plymouth is shipping to Selby and treatment charges range from $17.50 to $22 per ton, according to the grade. This item in itself amounts to approximately 30 cents per ton of ore treated aside from the freight

FIG. 8—LOWER FLOOR, BLACK OAK MILL, OLIVER FILTER IN BACKGROUND

and the fact that the smelter pays for gold at the rate of only $19 per ounce. At this writing the Plymouth is operating a 200-lb. experimental plant to determine the advisability of cyaniding the concentrates. It is also considering the possibility of cyaniding the Wilfley tailings instead of returning them for regrinding.

Black Oak Mill

The ore of the Black Oak is found in fissures in the "Soulsbyville granite," a notoriously hard rock consisting of true granite and granodiorite with ribs of diorite. It is a quartz gangue containing gold with small quantities of silver. About 40 per cent of the gold occurs in the free state and the remainder is associated with pyrite, arsenopyrite and very small amounts of galena. The gold and silver are the valuable constituents of the ore, the amount of lead in the galena being too small to make its recovery profitable.

The ore is hoisted from the shaft in self-dumping skips which discharge to the mine bin from which it is discharged over a grizzly. A rough sorting for the larger chunks of waste is carried on at the grizzly. The over-size is run through a 15-in. x 10-in. Blake crusher to the bin beneath, from which the ore is loaded through rack-and-pinion gates to cars and hand-trimmed to the mill. The mill, Fig. 6, is of 100-tons capacity, timber construction, built on a hillside with a down grade from the mine bin. The mill bins are slope-bottomed and have a capacity of 200 tons, sufficient for two days' run in case there is an interruption to hoisting from the mine.

Crushing and Classifying

The ore is fed from the mill bins to four five-stamp batteries, Fig. 7, by means of Challenge feeders actuated by the middle stamp stem, lime being added at the feeders in the desired proportion. The stamps weigh 1200 lb. each and make 106 6-in. drops per minute in the order of 1-5-3-2-4. The ore is crushed in a 4½-lb. cyanide solution. Three of the batteries are fitted with No. 18 Tyler "tan-cap" screens and one with a six-mesh screen. A 75-hp. motor drives the batteries.

The battery pulp is distributed to one simplex and one duplex Dorr classifier. The coarse product of the classifiers goes to a 4-ft. x 20-ft. Power and Mining Machinery Company tube mill and the fine to a 3½-in. centrifugal pump which is chain-belted to a 5-hp. motor and discharges to a 20-ft. x 10-ft. Dorr thickener.

The tube mill crushes 60 tons per twenty-four hours making 27 r.p.m. Danish pebbles are used at the rate of 4½ lb. per ton of ore crushed. It is driven by a 75-hp. motor. Seventy per cent of the discharge will pass 200-mesh. Instead of using lead acetate to assist in the precipitation, litharge is used by feeding it into the tube mill at the rate of 1 lb. per ton of ore. It is estimated that 70 per cent of the valuable constituents of the ore is in solution when it leaves the tube mill.

The tube mill is in a closed cricuit with the Dorr classifiers. The discharge goes to a bucket elevator with 4-in. x 8-in. buckets on 12-in. centers. This elevator has a lift of 16 ft. and a speed of 450 ft. per minute, returning the pulp to the classifiers. A 5-hp. motor drives the elevator and classifiers.

Decantation and Filtration

The fines from the Dorr classifier are sent by way of the centrifugal pump to the first Dorr thickener from which they are transferred by means of a Pohle air-lift to the first of a series of three Pachuca tanks, each 10 ft. x 30 ft. The slime is continuously agitated in these three tanks, finally overflowing the third tank to a second Dorr thickener the same size as the first. Here the pulp is brought to a consistency of 70 per cent mois-

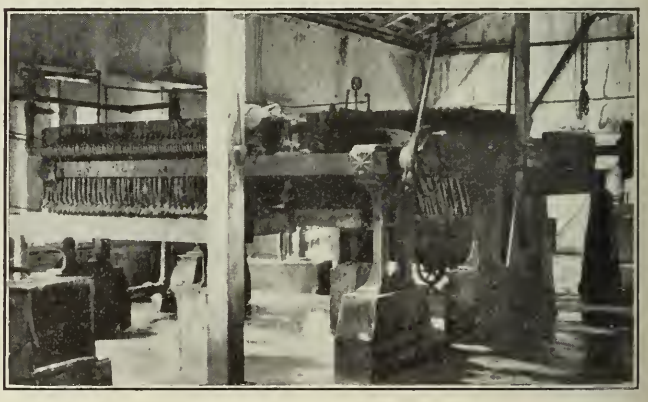


FIG. 9—SHRIVER AND MERRILL FILTER PRESSES, BLACK OAK MILL

ture (Sp. Gr. 1.32) and the overflow discharged to the collecting sump below the Oliver filter which also receives the pregnant solution from the filter.

The pulp from the second Dorr thickener goes to an Oliver continuous filter, 6 ft. x 12 ft. (Fig. 8) which makes a complete revolution in seven minutes. A 5-hp. motor drives the Dorr thickeners and Oliver filter.

Air for the Pachuca tanks and for discharging the cake from the Oliver filter is supplied under 45 lb. pressure by a 10-in. x 8-in. Ingersoll-Rand compressor working with a capacity of 100 cu. ft. of free air per minute, belted to a 25-hp. motor. Vacuum is furnished at 20 in. to 22 in. to the Oliver filter by a piston-inlet compressor working at 125 cu. ft. of free air per minute and driven by a 15-hp. motor.

The pregnant solution from the Oliver filter flows to a collecting tank of 600-gal. capacity, which, as noted, also receives the overflow of the Dorr thickener. From the collecting tank the solution is pumped by a 4½-in. x 6-in. Dorr horizontal duplex pump belted to a 5-hp. motor to a 34-frame Shriver filter press (Fig. 9), in which it is clarified. From the Shriver press the clarified solution goes to a 900-gal. tank in which the zinc dust is added and from which it is pumped to a 22-frame, 4-ft. Merrill press (Fig. 9) by a 5½-in. x 8-in. Platt triplex pump geared to a 5-hp. motor. The barren solution from the Merrill press is pumped to two 65-ton stock tanks where it is brought up to standard, 4½-lb. KCN per ton.

The zinc dust precipitate is loaded to an iron tray which is wheeled out and dried over an open fire. No acid treatment is given the precipitate, which is refined by slagging with borax and sand and melted in a No. 150 graphite crucible in an oil-fired Steele-Harvey tilting furnace.

Chemicals and Power

During the past year the consumption of chemicals per ton of ore has been as follows: Cyanide, 1.25 lb.; lime, 3.27 lb.; zinc, 1.30 lb.

All ore passing through the mill is sampled twice, once by a grab sample from each car as it is weighed and once by sampling at regular intervals at the feeder. Tailings are sampled automatically and the extraction as calculated from the head and tailing samples is checked against the actual bullion return, the two results usually agreeing within a small fraction of 1 per cent.

Power is purchased from the Sierra-San Francisco Power Company and delivered at 40,000 volts to the substation where it is stepped down for distribution at 440 volts. An average of power costs for the first two months of 1915 was 45 cents per ton of ore. Power is used as follows:

Machines.	Power.
Crusher	15 hp.
Stamps (20)	75 hp.
Tube mill	75 hp.
Centrifugal pump	5 hp.
Elevator and classifiers (2)	5 hp.
Compressor	25 hp.
Vacuum pump	15 hp.
Dorr thickeners (2) and Oliver filter.	5 hp.
Dorr pump	5 hp.
Platt pump	5 hp.
Return pump	25 hp.
Total	255 hp.

This indicates a consumption of 2.55 hp. per ton of ore treated.

Costs

An average for two years shows the following assays and extractions:

Year	Heads	Tails	Extraction
1913	$13.218	$0.574	95.58 per cent
1914	11.873	0.220	98.15 per cent

These figures are based on actual bullion recovery and tailings assays.

The following costs are given out:

Year	Tonnage	Power, supplies, etc.	Labor	Total
1913	25,853.7	$0.960	$0.620	$1.580
1914	11,518.8	1.331	0.908	2.239

The above costs include superintendence, clerical expense and all other overhead charges.

During 1914 the mine was carrying on extensive development work which limited production. On this account the mill was run at far less than normal capacity but as expenses were the same as with the full capacity there was a corresponding increase in the cost per ton. As the Black Oak was the first mill to cyanide these ores and 1913 was the first full year that it operated, it is reasonable to expect that the extraction record of 1914, when the operatives had had the benefit of some experience, will be maintained. For these reasons it is fair to judge the possibilities of this plant by its 1913 costs and 1914 extraction.

Comment

Two-stage crushing has been so universally adopted in other districts and so thoroughly discussed that there is hardly room for comment. Observations at these plants do not tend to the conclusion that it effects any saving in power but it is obvious that at such a mill as the Plymouth the form in which the pulp is discharged is a material advantage.

The Plymouth presents many innovations from a mechanical standpoint while the Black Oak was an innovation *in toto* so far as these ores are concerned.

While in general the ores may be considered similar there is sufficient difference to make a comparison difficult. One cannot but notice the difference in the power used in fine crushing and grinding, 0.43 hp. per ton in the Plymouth mill as against 1.5 hp. in the Black Oak. But the Plymouth ore is mixed with a soft slate while the Black Oak is associated with the extremely hard Soulsbyville granite which breaks much coarser in the stopes. This difference in hardness is brought out by the pebble consumption, 1.5 lb. per ton at the Plymouth against 4.5 lb. per ton at the Black Oak. Further the Hardinge mill discharges only 15-20 per cent of —200 material while the discharge of the Black Oak tube is 70 per cent of —200. It is probable also that the relative efficiencies of these two machines are a factor, as it is generally considered that a Hardinge mill consumes less power under the same conditions than a long tube.

Some comparison may be made of the relative economy of the two processes, especially with respect to the Black Oak whose detailed costs are presented. If we assume that 62½ per cent of the Plymouth ore is recovered on the plates and that the mill extraction is 90 per cent it appears that the extraction in the concentrating department is 73½ per cent. If we assume a $12 ore for the Black Oak, a recovery of 40 per cent on plates and an extraction on the concentrating machines corresponding to that of the Plymouth we should have a tailings loss of $1.91. This exceeds the corresponding loss from this source by cyaniding by $1.67 which is 9 cents more than the total costs for milling during 1913 which is the proper criterion of future service. Thus an attempt to follow the Plymouth system at the Black Oak would result in a loss per ton of $1.67 plus freight and smelter charges on concentrates and the difference in the value of the gold as paid for by the smelter, against which the only offset would be the difference in the cost of the two methods, amalgamation and concentration being accomplished at a considerably lower figure than cyaniding. Obviously cyaniding is the more economical method of treating these ores.

In the absence of detailed costs from the Plymouth a similar comparison can only be tentative. Under present conditions tailings losses are approximately 50 cents per ton, smelter charges, 30 cents and the difference in the rate of settlement for gold, say 15 cents. Freight charges are not available. If a 98 per cent extraction could be obtained so as to reduce the tailings losses by 40 cents the question would be whether the difference in milling costs would be more or less than the in-

creased saving, 40 cents, plus smelter charges, 30 cents, plus difference in payment for gold, 15 cents, plus freight on the concentrates and the cost of sacking.

From some information I have had regarding costs of treating these ores by amalgamation and concentration I am of the opinion that the present system is better adapted to the Plymouth ores even considering the greater tonnage of its plant than that of the Black Oak and the possibility that that 98 per cent extraction *might* be realized. In the absence of any data on cyaniding Mother Lode ores one cannot predict what saving could be made. I do not know about the Plymouth ore but many mines in this belt encounter graphite in sufficient amount seriously to interfere with cyaniding, which is a factor that would have to be taken into consideration.

While such a discussion is interesting from a theoretical point of view it must be borne in mind that the Plymouth mill was designed by a competent engineer and it is taken for granted that the system installed was selected as the most economical after due consideration of every phase. But it is interesting to note that there is a leaning toward a modification of the process to include cyaniding the concentrates and possibly the Wilfley tailings.

I am indebted to many officials and employees of the two companies whose operations are described, particularly Messrs. Roger Knox, superintendent; C. W. Hopkins, secretary, and F. W. Watts, mill superintendent of the Black Oak and S. R. Brown, mill superintendent of the Plymouth Consolidated.

San Francisco, Cal.

Efficiency of the Blast Furnace Operation

BY BIRGER F. BURMAN

Pure air contains besides oxygen and nitrogen about 0.04 per cent CO_2. It is also claimed that in the proportion assigned to nitrogen about 1 per cent consists of other rare inert gases such as argon, neon, krypton, zenon, helium, etc., as well as small quantities of hydrogen and water vapor. With the exception of water vapor only oxygen and nitrogen need be considered for practical purposes, and the composition of pure, dry air is therefore by many accepted to be:

	By Volume	By Weight
Oxygen	20.8 per cent	23.1 per cent
Nitrogen	79.2 per cent	76.9 per cent

As pure air is always accompanied by a certain amount of water vapor, dependent on the existing temperature and barometric pressure, the air mixture of oxygen, nitrogen and H_2O vapor, which concerns us directly, will constantly vary in composition. If pure air could be secured for practical purposes, the air mixture of oxygen and nitrogen with above composition would certainly be of maximum efficiency; and as only oxygen is of value for combustion the amount of this element as shown must give to the air mixture a 100 per cent efficiency.

Nitrogen and the other gases are not only inactive as far as combustion is concerned, but they dilute the products of combustion and absorb considerable amount of heat. However, they are not as harmful as H_2O vapor, which gas in addition must also be decomposed, thereby consuming fixed carbon according to the following reaction:

$$H_2O + C = H_2 + CO.$$

As 12-unit weights of carbon are involved, the consumption of fixed carbon will be 0.67 to every unit weight of H_2O vapor reduced. This carbon is a dead loss, but that is not all. The reaction cannot exist without addition of more heat. As it stands the loss is 1606 pound-calories per pound of H_2O vapor or 2408 pound-calories per pound of carbon involved. This heat is partly furnished by the sensible heat in the H_2O vapor and in the hot carbon, but even under favorable conditions it is not sufficient and extra carbon has to be utilized. In other words, the presence of water vapor lowers the temperature of combustion as it robs the pure-air combustion of a certain amount of heat.

The amount of H_2O vapor present in the blast is small, figured per cubic foot; but when millions are used in a day, the weight of water pumped into the blast furnace is enormous. It therefore becomes of supreme importance to endeavor to cut down the moisture content to the absolute minimum not only in order to save fuel, but also to secure a uniform composition of the blast, thus aiding the regular run of the operation.

If the air is at 60 deg. Fahr. dry and 47 deg. Fahr. wet* the relative humidity is 35 per cent and the weight of H_2O vapor per cubic foot of air mixture will be 0.000289 lb. At another time the respective temperatures are + 0 deg. Fahr. and — 2 deg. Fahr., giving also a 35 per cent humidity, but the weight of H_2O vapor will now be only 0.000024 lb. If during twenty-four hours a blast furnace receives 60,000,000 cu. ft. of blast, the water pumped in each case will be 17340 lb. and 1440 lb. Of course, in case of the colder blast only about 53,069,000 cu. ft. had to be pumped in order to make it equal the 60,000,000 at the higher temperature, but this makes the comparison still more unfavorable for the warmer and more humid blast, as the drier air will contain only 1274 lb. of water.

By cooling the air the H_2O vapor can be eliminated, but it is an expensive operation. While a dry-blast plant ought to be built at every blast-furnace plant the cost is by many considered prohibitive. A partial improvement may be secured by carrying the blast intake to the outside of the blowing engine room, thus pumping air of lower temperatures at little or no cost—if the first cost of building the intake be excepted. Water-cooling also forms another kind of less expensive but at the same time less satisfactory arrangement as far as results are concerned when compared with the dry-blast plant.

Volumes vary constantly, dependent on the temperatures and pressures to which they are subjected. One cubic foot of air mixture (containing no moisture) at zero will at a higher temperature, with the pressure remaining the same, take a larger volume, of which 1 cu. ft. must weigh less. The percentage of oxygen has not changed; consequently the amount of this element must also become less per cubic foot at the higher temperature. If now H_2O vapor is added, the weight of the oxygen in the cubic foot of air mixture will be somewhat less in the former case but much more so in the latter case, due to the increased amount of H_2O vapor at higher temperatures.

As oxygen is the only desirable element for combustion it is important to deliver to the blast furnace not only pure, dry air but also a regular amount of same. If, for instance, I was delivering 40,000 cu. ft. per min. under any and all conditions, I would constantly vary the amount of oxygen, which variations in case of no refrigeration would be still more intensified. The result would be difficulties in keeping up a regular run of the blast furnace with accompanying losses.

The only proper thing to do is to reverse these conditions and deliver to the blast furnace a constant amount of pure, dry air under any and all conditions, which, of course, will be equivalent to a constantly variable volume of air mixture per unit of time. At the same time the amount of H_2O vapor should be cut down to the minimum.

*At a bar. pressure of 29".

It will not be possible to deliver the proper amount of oxygen without a table giving the number of revolutions per minute at any desired temperature and relative humidity. Such a table is a necessary guide to the blowing-room foreman.

Before such a table can be worked out the displacement of the blowing cylinder must be ascertained. This should be carefully done, and after all measurements have been established the following calculations will determine it:

V = Volume of air cylinder, empty, including the two clearances and all the voids at the ports, ...cubic feet.

V_1 = Volume of the two clearances and all the voids at the ports minus volume of piston rod equal to the depth of one clearance,.....cubic feet.

V_2 = Volume of one piston,.....cubic feet.

V_3 = Volume of one piston rod of the length of the stroke plus the depth of two clearances, ...cubic feet.

V_4 = Volume of the open space per revolution:

$= 2V - (2V_2 + V_3)$ cubic feet.

In degrees Fahrenheit:

Dry temperature of air mixture, going into the cylinder .....t

Dry temperature of blast, leaving the cylinder ..... t_1.

In inches of mercury:

Barometric pressure.....P.

Blast pressure—absolute (gage + barometer) ..... P_1.

V_5 = Volume of air mixture (blast) per revolution at any time for one air cylinder:

$$= V_4 - \left(2V_1 \times \frac{459.4 + t}{459.4 + t_1} \times \frac{P_3}{P}\right) \text{ cubic feet.}$$

This formula may be considered close enough for practical purposes and represents the net displacement at any time. It can readily be seen that the volume of air mixture is dependent on a number of factors, and as the volume of the air, which is trapped in the space V_1, also is undergoing constant changes, the chances of success in working out a standard table of blast regulation, that would be at the same time correct and practicable, is very slight. However, as it would neither be practicable to have a separate table made out for the displacement, covering any and all conditions, a fairly accurate figure for volume V_5, to be used only as a basis for the Table of Blast Regulation, may be had by adopting the following analysis:

The rise in temperature of the blast during its passage through the blowing engine is considerable. Observations made by the author have given averages as high as 150 deg. Fahr. The blast pressure, we know, will vary anywhere from 8 to 20 lb. per square inch. Let us therefore assume that one atmosphere is the average compression; however, any plant probably has the average for a considerable length of time and in such a case this would be the figure to use. When the gage pressure is one atmosphere, the absolute pressure will be about two, consequently when the delivery port is closed and the piston starts on its return trip, the air mixture, trapped in space V_1, will be subjected to a contraction in volume of approximately 0.75, due to the temperature, and an expansion of about 2, due to the pressure, making a total expansion of about 1.5. The formula will therefore be $V_4 - 3V_1$, which, in the absence of records for temperatures and pressures, may be adopted.

Having established the displacement per revolution, the next step will be to assume a standard for the weight of pure, dry air to be delivered per minute during any and all conditions.

As the barometric pressure constantly varies, and it is not practicable and indeed not necessary either to have a table for every change; and, furthermore, as the barometer usually stands around 29 in., there need be only two tables in the blowing room: one, covering pressures between 28.5 in. and 29.4999 in., called the 29-in. table, and another table, taking in pressures between 29.5 in. and 30.4999 in., called the 30-in. table.

The table may be worked out for any range of temperatures but it will be found that 0 deg. to 100 deg. Fahr. is a very suitable one. Of course, in colder climates, the temperature will go lower than 0 deg. Fahr., just as in warmer countries it might rise above 100 deg. Fahr. In such a case the range should be extended to include such temperatures.

It is not necessary to include every per cent vapor saturation, 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 per cent answering all practical purposes.

EXAMPLE

Work out a table of blast regulation for 29-in. barometer pressure when: The blowing cylinder is 84 in. in diameter × 60-in. stroke and 3000 lb. is the standard for weight of pure, dry air to be delivered per minute under any and all conditions.

Blowing cylinder displacement:

V = 229.5 cu. ft.
V_1 = 7 cu. ft.
V_2 = 30 cu. ft.
V_3 = 2.3 cu. ft.
V_4 = 396.7 cu. ft.
V_5 = 396.7 — (3 × 7) = 375.7 cu. ft.

Net displacement is therefore 375.7 cu. ft.

In the formulas below:

t denotes dry temperature of air mixture in degrees Fahrenheit.

P denotes barometric pressure in inches of mercury.

P_1 denotes vapor pressure in inches of mercury.

P_2 denotes air pressure in inches of mercury.

"Standard conditions" represent 32 deg. Fahr. and 29.9212 in. barometric pressure.

Weight of dry air in 1 cu. ft. of any air mixture is

$$0.080728 \times \frac{459.4 + 32}{459.4 + t} \times \frac{P_2}{P} \times \frac{P}{29.9212} = \frac{1.32581 \times P_2}{459.4 + t} \text{ pounds.}$$

In case of no moisture being present the factor $\frac{P_2}{P}$ disappears and the formula will give $\frac{1.32581 \times P}{459.4 + t}$ pounds.

Applying these formulas to our case for 0 deg. Fahr. the weight of dry air in 365 cu. ft. of air mixture with no moisture present (relative humidity = 0 per cent) will be:

$$365\left(\frac{1.32581 \times 29}{459.4}\right) = 30.54782 \text{ lb.}$$

When the relative humidity is 100 per cent the vapor pressure P_1 is 0.0383 in., the air pressure P_2 is 28.9617 in., the barometric pressure P is 29 in., and the weight of dry air in 365 cu. ft. of air mixture will be:

$$365\left(\frac{1.32581 \times 28.9617}{459.4}\right) = 30.50748 \text{ lb.}$$

By dividing the respective weights into 3000 the quotient will be the revolutions per minute necessary to deliver the proper volume of dry air; thus for 0 per cent humidity 98.21 r.p.m. and for 100 per cent humidity 98.34 r.p.m.

The difference 98.34 — 98.21 = 0.12 may be equally distributed on the miscellaneous relative humidities and the revolutions per minute will therefore be:

Relative Humidity Per Cent	R.P.M.
0	98.21
10	98.22
20	98.24
30	98.25
40	98.26
50	98.28
60	98.29
70	98.30
80	98.32
90	98.33
100	98.34

The table will now be completed for 0 deg. by inserting these figures for revolutions per minute.

Applying again the formulas to our case for 100 deg. Fahr., the weight of dry air in 365 cu. ft. of air mixture with no moisture present (relative humidity = 0 per cent) will be:

In the following calculations the figure 365 has been used so as not to change calculations that had already been made. This will not alter the methods of calculations, although it is incorrect for the example itself.

$$365\left(\frac{1.32581 \times 29}{559.4}\right) = 25.08706 \text{ lb.}$$

When the relative humidity is 100 per cent the vapor pressure P_1 is 1.916 in., the air pressure P_2 is 27.084 in., the barometric pressure P is 29 in. and the weight of dry air in 365 cu. ft. of air mixture will be:

$$365\left(\frac{1.32581 \times 27.084}{559.4}\right) = 23.42958 \text{ lb.}$$

By dividing the respective weights into 3000 the quotient will be the revolutions per minute necessary to deliver the proper volume of dry air; thus for 0 per cent humidity 119.58 r.p.m. and for 100 per cent humidity 128.04 r.p.m.

The difference $128.04 - 119.58 = 8.46$ may in this case also be equally distributed on the miscellaneous relative humidities and the revolutions per minute will therefore be:

Relative Humidity Per Cent	R.P.M.
0	119.58
10	120.43
20	121.28
30	122.12
40	122.97
50	123.82
60	124.66
70	125.51
80	126.35
90	127.20
100	128.04

Complete the table for 100 deg. Fahr. by inserting above figures.

Having the two extremes recorded, the next step will be to complete calculations for each humidity separately. For instance, select the 100 per cent column and divide the difference $128.04 - 98.34 = 29.70$ into ten equal parts of 2.97 each. Complete the column for every tenth degree, which for 10 deg. Fahr. will give $98.34 + 2.97 = 101.31$, for 20 deg. Fahr. = 104.28, etc., until the revolutions per minute for 90 deg. Fahr. has been recorded. Thereafter do likewise for all temperatures between 0 deg. and 10 deg., 10 deg. and 20 deg., 20 deg. and 30 deg., etc., until the entire 100 per cent column has been completed. The other columns are figured out in a similar way.

It may be inconvenient to give the standard for dry air blown per minute in pounds, but this may easily be overcome by selecting a certain figure for the volume in cubic feet blown per minute at a certain temperature and relative humidity, and calculate the weight of dry air in this volume.

Example: What is the standard weight when I want to blow the equivalence of dry air in 40,000 cu. ft. of air mixture at 50 deg. Fahr. and 50 per cent vapor saturation?

The vapor pressure for 50 deg. Fahr. and 100 per cent saturation is 0.360 in., the vapor pressure for 50 deg. Fahr. and 50 per cent saturation $= 0.360 \times 0.50 = 0.180$ in., the air pressure for 50 deg. Fahr. and 50 per cent saturation is 28.82 in., all for a barometric pressure here assumed to be 29 in.

The weight of dry air in the 40,000 cu. ft. of air mixture is $40{,}000\left(\frac{1.32581 \times 28.82}{509.4}\right) = 3000$ lb. and the standard will therefore be 3000 lb. per minute, or pounds per 100 lb. of pig iron (see below).

Two 29-in. and 30-in. tables as described are an absolute necessity in any blowing room, even though they may not give entirely correct figures for the revolutions per minute due to causes over which there is no control. Generally speaking, the figures give good practical results. However, there are other factors that interfere with correct results even should T blow the right number of revolutions. It is therefore important to eliminate, if possible, such disturbing elements of which the following may be the most important:

1. Leakages in the air cylinders, valves, stoves, cold and hot blast mains. These can be overcome, and the stoppage of all such leaks should be the first work in the line of improvements.

2. Bad conditions of the blowing engine itself. This can also be overcome by frequently using the indicator, which is necessary in order to keep the valves set right.

3. Disturbances in the blast furnace, causing sudden differences in pressure of the blast.

The air mixture may enter the blowing cylinders under the following conditions:

1. As dry blast, when refrigeration has been carried on to the practical limit. In this case both the temperature and pressure will be almost constant with humidity practically nil. The displacement will likewise be a near constant, wherefore the number of revolutions must, as a matter of course, vary little or nothing. There will under such conditions be no need of any guiding "Table of Blast Regulation."

2. As partially dried blast, when the air mixture is more or less cooled, either artificially or by means of carrying the blast intakes to the outside of the blowing engine room. The manner of taking the temperatures will be different. In the former case provisions must be made in the air line close to the intakes of the blowing cylinders for the reading of the two thermometers. No slinging is required as the air current is swift enough. The dry bulb thermometer may be stationary, but the wet bulb should be so placed that the muslin can be dipped in the water, which must be pure and clean. Even a wick attached to the wet bulb and placed in a bottle of pure, clean water will in this case answer the purpose. This has the additional advantage of making the wet bulb also stationary. When the blast intake is carried to the outside of the building a similar wick arrangement for the wet bulb may do, placed either as above or at the entrance of the intake.

3. As natural air, taken directly from the blowing engine room. In this case sling psychrometer must be used and it is strongly recommended that the type used by the Weather Bureau be selected. In this the two thermometers are mounted in a frame, whirled around by means of shafting and miter gearing, the whole being encased, thus insuring the safety of the thermometers.

REPORT NO.

During the day of — On Blast Blown Into Blast Furnace No.

Time	Temperature, Deg. F.						Pressures					Total Number of Revolutions Blown by Engine		Relative Humidity, Per Cent
	Air going into the blowing engines			Blast			Inches of mercury			Pounds per sq. in. Blast				
	Dry	Wet	Diff.	Leaving Blowing Engines	At the Entrance of Stoves	At the Blast Furnace	Barometer	Vapor	Air	In the Blowing Room	At the Blast Furnace	No.	No.	
6- 7														
7- 8														
8- 9														
9-10														
10-11														
11-12														
12- 1														
1- 2														
2- 3														
3- 4														
4- 5														
5- 6														
6- 7														
7- 8														
8- 9														
9-10														
10-11														
11-12														
12- 1														
1- 2														
2- 3														
3- 4														
4- 5														
5- 6														
Total and av..														

NOTE:
Vapor pressure is determined by means of Weather Bureau's Psychrometric Tables and air pressure = difference between the barometric and vapor pressures.
Relative humidity is given directly in the Weather Bureau's Psychrometric Tables, when the Depression of wet-bulb thermometer as shown in third column by "Diff." is known.
When using these records for blast furnace tests of several days' duration, averages must be taken on all reports combined. Do not establish average on averages.

TABLE OF BLAST REGULATION

For Barometric Pressure ..... Inches of Mercury

Standard for weight of dry air blown per minute, pounds
Displacement of blowing cylinder per revolution, cubic feet
R.p.m. as shown give the same weight of dry air

	Dry Temp. Deg. F.	Relative Humidity										
		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
		r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.	r.p.m.
	0	98.21	98.22	98.24	98.25	98.26	98.28	98.29	98.30	98.32	98 33	98.34
	1											98.64
	2											98.94
	3											99.23
	4											99.53
	5											99.83
	6											100.12
	7											100.42
	8											100.72
	9											101.01
	10	100.35	100.44	100.54	100.64	100.73	100.83	100.93	101.02	101.12	101.22	101.31
	11											101.61
	12											101.90
	13											102.20
	14											102.50
	15											102.79
	16											103.09
	17											103.39
	18											103.68
	19											103.98
Figures, inserted, are for exhibition only. They are based on a standard supply of 3000 pounds of dry air delivered per minute by blowing cylinders of 365 cu. ft. displacement.	20	102.49	102.65	102.84	103 03	103.20	103.39	103.57	103.74	103.92	104 11	104.28
	21											104.57
	22											104.87
	23											105.17
	24											105.47
This table has been completed for 100 per cent relative humidity only and for every 10 deg. of the other humidities; this has been done in order to show methods of working it out.	25											105.76
	26											106 05
	27											106.35
	28											106 65
	29											106.95
Barometric pressure=29 in.	30	104.62	104.87	105.15	105.41	105 67	105.94	106 20	106.46	106.72	107 00	107.25
Working barometric pressure=28.5 in. to 29.4449 in.	80	115.30	115.94	116 68	I17.34	118.03	118.72	119 38	120 07	120.75	121.42	122.10
	81											122 39
	82											122.69
	83											122 99
	84											123.29
	85											123 59
	86											123 89
	87											124 18
	88											124 48
	89											124 78
	90	117.44	118.16	118.98	119.73	120 50	121 27	122.02	122 79	123 55	124.31	125.07
	91											125.37
	92											125.67
	93											125.96
	94											126.26
	95											126.56
	96											126.86
	97											127 15
	98											127 45
	99											127.75
	100	119 58	120.43	121.28	122.12	122 97	123 82	124 66	125.51	126.35	127.20	128.04

When refrigeration is made on the compressed air mixture either the second or third condition may take place. The manner of recording the temperatures will be accordingly.

Temperature readings need not be taken oftener than once an hour. However, it is important, that they are made on regular intervals, and it is a good policy to always do it on the hour.

There may be other methods of determining the amount of H_2O vapor in the atmospheric air as for instance by means of sulphuric acid, but, while this is the most correct one, it is hardly a practical method for continuous observations.

When the temperatures are known, the vapor pressure and relative humidity are determined by means of psychrometric tables, of which the one prepared by Prof. C. F. Marvin of the U. S. Weather Bureau is very complete.

By carefully conducting the operations in the blowing room it is possible to furnish a blast of more uniform quality. But this quality must be measured with some standard; otherwise I do not know its value. As was previously stated a certain air would be 100 per cent efficient if no moisture was present, because it would then contain the maximum amount of oxygen. Consequently this is the standard I need. But the volume must likewise at the same time be given. Therefore, while any convenient figure may be chosen, the air at "standard conditions" is the most logical. The weight of 1 cu. ft. of pure, dry air is then 0.080728 lb., but as this is too small a quantity 1000 cu. ft. may be more suitable. The standard will consequently be the weight of 1000 cu. ft. of pure, dry air at 32 deg. Fahr. and 29.9212 in. barometric pressure. This weight is 80.728 lb. If the air mixture, used at any time, is converted into volume at "standard conditions," the weight of pure, dry air in 1000 cu. ft. of this air mixture, multiplied by 100 and divided by 80.728, will give the air efficiency of the blast.

It has been shown above that the "Table of Blast Regulation" must be based on a standard weight of pure, dry air per minute. Of course, this standard may be assumed to correspond with a certain weight of pig iron produced. If, for instance, the standard in question is 3000 lb. per minute and the blast furnace is expected to turn out, say, 700 lb. of pig iron during the same unit of time, the standard for dry air per 100 lb. of pig iron would be 428.6 lb. Variations from this figure would in a certain measure indicate the uniformity of operations in the blowing room and will give the blast efficiency itself. Suppose 460 lb. of dry air had been blown per 100 lb. of pig iron, the blast efficiency would be $100 - \left(\frac{(460 - 428.6)100}{428.6}\right) = 92.67$ per cent.

When all the information is on hand calculations should be made on a certain small unit, as for instance, 1000 lb. of pig iron produced. The figures will otherwise be too bulky.

CALCULATIONS TO DETERMINE THE VALUE OF BLAST PRODUCTION

Determine first the time for which calculations shall be made. Assume this to be twenty-four hours.

The displacement of the air cylinder will next be considered and figured out as previously shown. In the formula

$$V_4 - \left(2V_1 \times \frac{459.4 + t}{459.4 + t_1} \times \frac{P_3}{P}\right)$$

t, t_1, P and P_3 are the average figures for the time in question and V_5 will give the result, which is the volume at existing conditions.

In degrees Fahrenheit:

t denotes dry temperature of air mixture, entering the blowing cylinders.

t_1 denotes dry temperature of air mixture, leaving the blowing cylinders.

t_2 denotes dry temperature of air mixture at entrance of stoves.

t_3 denotes dry temperature of air mixture at the blast furnace.

t_2 and t_3 are to be used for heat in the blast at these temperatures in connection with stove tests only.

In inches of mercury:

P denotes average barometric pressure.

P_1 denotes average vapor pressure (as given by the weather bureau's psychrometric tables).

P_2 denotes average air pressure and equals $P - P_1$.

P_3 denotes average absolute pressure of blast, leaving the blowing cylinders, and equals $P +$ gage pressure.

"Total pig" denotes total weight in pounds of pig iron, produced during the twenty-four hours.

$$\text{"Pig"} = \frac{\text{"total pig"}}{100}.$$

"Total revolutions" denotes total revolutions blown during the twenty-four hours.

"Total volume" denotes total volume of air mixture, blown during the twenty-four hours as per conditions V_5 and = "total revolutions" $\times$ V_5 cubic feet.

A. Volume of air mixture per 100 lb. of pig iron, produced $= \frac{\text{"total volume"}}{\text{"pig"}}$ cubic feet.

B. Weight of dry air in this air mixture

$$= A\left(\frac{1.32581 \times P_2}{459.4 + t}\right) \text{lb.}$$

C. Weight of H_2O vapor in this air mixture

$$= A\left(0.080728 \times \frac{459.4 + 32}{459.4 + t} \times \frac{P_1}{P} \times \frac{P}{29.9212}\right) 0.622.$$

$$= A\left(\frac{0.82465 \times P_1}{459.4 + t}\right) \text{lb.}$$

D. Weight of air mixture (blast) $= B + C$ lb.

At standard condition (32 deg. Fahr. and 29.9212-in. barometric pressure):

E. Volume of air mixture (blast)

$$= A \times \frac{491.4}{459.4 + t} \times \frac{P}{29.9212} \text{cu. ft.}$$

F. Volume of vapor in the air mixture $= \frac{16C}{0.81}$ cu. ft.

G. Volume of dry air in the air mixture $= E - F$ cu. ft.

In per cent the air mixture contains:

H. Vapor $= 100F \div E$ volume per cent.

I. Dry air $= 100 - H$ volume per cent.

K. Number of 1000 cu. ft. in the blast at standard conditions $= \frac{E}{1000}$.

L. Weight of dry air in the blast per 1000 cu. ft. at standard conditions $= \frac{B}{K}$ lb.

M. Air efficiency of the blast $= \frac{L}{0.80728}$ per cent.

N. Weight of water pumped into the blast furnace during the twenty-four hours $= C \times$ "pig" lb.

O. Heat in the air mixture, when entering the blowing cylinders (convert t deg. Fahr. into T deg. C.):

$G(0.0189T + 0.0000017T^2)$ pound calories.

$F(0.021\ T + 0.000009\ T^2)$ pound calories.

Total (————) pound calories.

Q. Heat in the blast when leaving the blowing cylinders (convert t_1 deg. Fahr. into T_1 deg. C.):

$G(0.0189T_1 + 0.0000017T_1^2)$ pound calories.
$F(0.021\ T_1 + 0.000009\ T_1^2)$ pound calories.
Total (————) pound calories.

R. Heat in the blast at entrance of stoves (convert t_2 deg. Fahr. into T_2 deg. C., and use only in connection with stove tests):

$G(0.0189T_2 + 0.0000017T_2^2)$ pound calories.
$F(0.021\ T_2 + 0.000009\ T_2^2)$ pound calories.
Total (————) pound calories.

S. Heat in the blast at entrance of the blast furnace (convert t_3 deg. Fahr. into T_3 deg. C. and use only in connection with stove tests):

$G(0.0189T_3 + 0.0000017T_3^2)$ pound calories.
$F(0.021\ T_3 + 0.000009\ T_3^2)$ pound calories.
Total (————) pound calories.

To be Used Only in Connection with Blast Efficiency	Heat in Pound Calories	In Per Cent of Total Heat Q
Heat furnished by the atmosphere $=O$	.....	.....
Heat furnished by the blowing engines $=Q-O$	.....	.....
Total	.....	100.00

To be Used Only in Connection with Stove Tests and Blast Furnace Efficiency:	Heat in Pound Calories	In Per Cent of Total Heat S
Heat furnished by the atmosphere $=O$	.....	.....
Heat furnished by the blowing engines $=Q-O$	.....	.....
Heat furnished by the stoves $=S-R$	.....	.....
Heat lost in transfer between blowing engines and stoves $=R-Q$	.....	.....
Total	.....	100.00

U. Standard weight of dry air per 100 lb. of pig iron, produced, assumed to be.....Pounds

W. Dry air delivered in excess $= B - U$ pounds.

Y. Blast efficiency $= 100 - \left(\frac{100W}{U}\right)$ per cent.

Technical Society Meetings and Lectures at the National Exposition of Chemical Industries

The following program is complete to date for America's first National Exposition of Chemical Industries, which opens in Grand Central Palace, New York City, on Monday, Sept. 20. The managers, Messrs. Nagelvoort and Roth, working with the co-operation of the International Exhibition Company, deserve a very great deal of credit for this diversified and interesting program, and also for the equally fine motion-picture program. Credit is given by the managers to all who have assisted in the endeavor to make the exhibition a success, especially the advisory committee and the Bureau of Commercial Economics of Washington, through their assistance in securing speakers and their kindness is loaning films. The program follows:

Monday, Sept. 20

Opening day. The exposition will be formally opened by a member of the Cabinet from Washington.

Tuesday, Sept. 21

2 p. m.—HOWARD GROSS, president Tariff Commission League, "Tariff Question," followed by discussion.

8 p. m.—Meeting the New York Section of American Electrochemical Society, under whose auspices the following papers will be given:

Introductory remarks by the chairman, Dr. COLIN G. FINK.

D. T. PIERCE, Barber Asphalt Co., "Asphalt and the Brownian Movements of the Colloids of Trinidad Asphalt" (an illustrated lecture).

LINN BRADLEY, the Research Corporation, "Solution of Smoke, Dust and Fume Nuisance by Electrical Precipitation."

HARRINGTON EMERSON, the Emerson Co., "Efficiency in the Conservation of our Natural Resources."

Wednesday, Sept. 22

2 p. m.—FREDERICK W. KEOUGH, National Association of Manufacturers, "Accident Prevention in the Chemical Industries."

WELDING RING, President American Exporters' Association, "Transportation and Shipping Facilities with Foreign Countries."

J. L. LIGHTNER, Hershey Chocolate Co., "The Manufacture of Chocolate."

8 p. m.—THOS. H. NORTON, Department of Commerce, "Foreign Markets for American Chemicals."

I. F. STONE, President National Aniline & Chemical Co., "The Aniline Dye Situation."

Thursday, Sept. 23

2 p. m.—Meeting of the American Paper & Pulp Association (Technical Section), under whose auspices the following papers have been promised:

Welcoming address by President FRANK L. MOORE.

D. L. BELLINGER, "Some Experiments in Refining Groundwood Slivers."

F. G. WHEELER, "A Method of Determining the Current Capacity of a Cell in an Electrolytic Bleach Plant."

MAX CLINE, "The Possibilities of Accurate Determinations of Groundwood in Papers."

The following lectures will also be given on this day:

2 p. m.—J. L. TAYLOR, Bureau of Explosives, "Explosives."

H. A. HUSTON, German Kali Works, "Potash."

G. B. HECKEL, New Jersey Zinc Co., "Paint."

ROBT. L. FRINK, president Frink Pyrometer Co., "The Relation of Chemistry and Mechanical Manipulation to the Evolution of the Glass Industry."

8 p. m.—CHARLES V. BACON, consulting chemist, "Manufacture and Uses of Vegetable Oils."

GEORGE FRANK LORD, DuPont DeNemours Powder Co., "Chemical Effect of Dynamiting the Soil."

PERCY WILSON, secretary Association American Portland Cement Manufacturers, "The History of Cement."

In the evening a smoker has also been arranged by the Chemists' Club, to be held at its clubhouse, 50 East Forty-first Street, for visiting chemists:

Friday, Sept. 24

2 p. m.—W. D. COOLIDGE, General Electric Co., "The 'X-Ray.'"

PHILLIP SHARPLES, Barrett Manufacturing Co., "The Development of Refined Tars for Use in Road Construction and Maintenance."

8 p. m.—Joint meetings of the New York Section American Chemical Society and the American Institute of Chemical Engineers, under whose auspices the following lectures will be given:

S. P. SADTLER, S. P. Sadtler & Sons, "Some American Contributions to Industrial Chemistry."

L. H. BAEKELAND, "Chemical Industry."

Saturday, Sept. 25

2 p. m.—RAYMOND F. BACON, director Mellon Institute, "Research and Progress in American Manufacturing."

For Saturday evening Dr. Thomas H. Norton has promised a paper on the results of some special work which he has done in the past two years, and which is hoped to have far-reaching consequences.

The Open Hearth Versus the Electric Furnace in the Manufacture of Commercial Steels

BY SIDNEY CORNELL

There has been a great deal of discussion lately about the cost of making steel in the electric furnace in competition with the open-hearth furnace, and recently the assertion has been made that the electric furnace can compete with the open hearth in the manufacture of commercial steels on a large scale.

The electric furnace has successfully competed in quality and in cost with the crucible process, and in many instances can produce steel at a cost less than in the small converter or Tropenas process, and is being used for making small and special castings at a very good showing in cost. The assertion that the electric furnace can do all that the modern open-hearth furnace can do in large and organized plants, and on commercial steels, is open to doubt, and the following analysis of the facts may be of value in clearing up the situation. The matter must be considered from a commercial standpoint, and for the manufacture of steel for rails, structural shapes, merchant bar, etc., the problem is nothing more than a balance of detailed costs and investment. In order to do this the following table has been compiled from data from a year's operation of a large open-hearth plant in a well-known steel company, and compared with what is claimed to be practice obtainable in an electric furnace plant of the same capacity.

The following comparison is made from records for an open-hearth plant consisting of 80-ton furnaces, having a production of about 200 tons of ingots per day for each furnace, and compared with a 20-ton electric furnace having approximately the same capacity per day. This comparison must be made assuming that an electric furnace plant of some ten furnaces is substituted for a plant of open-hearth furnaces containing ten furnaces, each plant being equipped with the necessary auxiliary apparatus, mixers, scrap yards, cinder ladles, ingot equipment, tracks, etc., etc.

The cost of a modern open-hearth plant with 80-ton units, is approximately $275,000 per furnace, including all auxiliary equipment, building, etc. The cost of a 20-ton electric furnace of the most advanced type is estimated at $500,000 per unit, and including the necessary electrical equipment. In connection with the electric furnace it is assumed that blast-furnace gas would be converted into electricity, and that modern practice cleans all blast-furnace gas, thus making the gas engine and equipment chargeable to the electric-furnace equipment, but not the gas-cleaning plant.

Table I is a tabulation of the materials necessary to make a ton of steel, and whether the electric or the open-hearth furnace is used or not, the quantity of raw materials is approximately the same. It is argued that the electric furnace can use inferior materials. Inferior materials necessarily are not in the most advantageous shape to handle, and often are more bulky than those of better quality, so that although in the auxiliary charge the electric furnace might use a slightly smaller quantity this would be offset in the more bulky principal materials, and accordingly more troublesome to handle.

The electric furnace will consume the same raw materials in the making of a ton of steel, the molds used will be the same, and the only credit will then be refractories, and producer gas, from the tabulation of Table I.

In Table I the cost of rebuilding is included in the refractories cost, which is given totaled for the electric furnace, and the cost of power is taken at a low figure $0.007 per kw.-hr. In a commercial plant such as is under consideration, the labor distribution for the handling of the quantity of materials necessary to make each ton of steel will be the same for either type of furnace, and in this work organization of a force is as imperative for a plant of electric furnaces as for an open-hearth plant. Further, an electric-furnace plant, being part of a steel works, would have to bear its share of the non-producing departments, and accordingly Table II applies for both purposes.

Table III (Labor in Repairs) will also hold good as much for an electric-furnace plant as for an open-hearth plant, because as may be noted, the large portion of the charges are not for the furnace proper, and the furnace proper is a comparatively small item.

Table I—Materials Charged per Ton of Steel

Material	Pounds per Ton of Steel	Rate Cost per Pound	Cost per Ton Steel Open Hearth	Cost per Ton Steel Electric Furnace
Hot metal	872	$0.005	$4.360	$4.360
Cold pig	376	0.005	1.880	1.880
Chills	17	0.008	0.136	0.136
Moulds	15	0.010	0.150	0.150
Castings (iron scrap)	5	0.008	0.040	0.040
Pit scrap	64	0.007	0.448	0.448
Ingot butts	46	0.007	0.322	0.322
Turnings	41	0.005	0.205	0.205
Sheet scrap	99	0.006	0.594	0.594
Miscellaneous steel scrap	852	0.005	4.260	4.260
Limestone	119	0.0005	0.059	0.059
Ferro-manganese	16	0.020	0.320	0.320
Ferro-silicon	0.5	0.010	0.005	0.005
Iron ore	108	0.0012	0.129	0.129
Fluor spar	4	0.0009	0.003	0.003
Coal	4	0.0009	0.003	0.003
Aluminum	0.25	0.2000	0.050	0.050
New moulds (40 lb. per ton)	25	0.010	0.250	0.250
Cupola relining (Dolomite)	.....	.....	0.010	
Calcined dolomite	105	0.0011	0.123	
Magnesite	3.5	0.010	0.035	
Chrome ore	1	0.009	0.009	0.240
Clay	5	0.0006	0.003	(total)
Loam	9	0.0005	0.004	
Coke	16	0.0014	0.022	
Ladle brick	0.9	0.010	0.009	0.009
Stoppers	0.012	0.010	0.0012	0.0012
Sleeves	0.214	0.028	0.0061	0.0061
Nozzles	0.021	0.010	0.0021	0.0021
Rebuilding	.....	.....	0.1400	.....
Producer gas	5250 cf.	10c M. cf.	0.5250	.....
Electric power	605 kw.-hours	0.007 kw.-hour	.....	4.220
Total			$14.1034	$17.6924

Table II—Labor Cost in Making Steel

Function	Item	Cost per Ton of Steel
General	General works	$0.092
	Steam	0.003
	Water	0.007
	Electric light and power (for cranes, etc.)	0.012
	Yard switching	0.045
	Shops	0.065
Producing labor	Superintendents and foremen	0.009
	Clerks, Timekeepers and Weightmasters	0.014
Stocking	Unloading and handling from cars	0.042
	Filling boxes from bins	0.015
	Cranemen, etc., handling boxes	0.019
	Narrow-gage engineers, etc	0.013
Charging	Charging machine men	0.012
	Pull-ups and cranemen	0.009
	Metal mixed labor	0.020
Melting	Melting and gas tending (or electrodes)	0.170
	Lining hot metal ladles	0.006
	Bottom making	0.017
Casting	Ladle lining and stopper setting	0.040
	Mould handling	0.012
	Scrap and cinder labor	0.062
All other	Ingot distribution	0.004
	Mould yard labor	0.022
	Scrap and cinder drop labor	0.048
	Inspection and stripping ingots	0.001
	Transportation	0.035
	Other general	0.035
	Total	$0.829

The fixed charges against the open-hearth furnace, costing $275,000 per unit, and figured at 16 per cent for interest, depreciation and taxes, becomes $0.610 per ton of steel produced. The cost of an electric-furnace plant of the same daily capacity is approximately $500,-

TABLE III—LABOR IN REPAIRS

Item	Cost per Ton of Steel
Narrow gauge, ladles, etc	$0 007
Charging machines	0 003
All machinery except charging	0 017
Furnaces	0 009
Metal mixers	0 005
Grinders and all drying apparatus	0 002
Ingot stripper	0 002
Scrap drop	0 001
Buildings	0 002
Yards, sewers, etc	0 006
Bins, tracks, trestles, etc	0 006
Total	$0 060

000 per unit, and including a 4500-kw. electrical equipment per unit, which, assuming the same rate of depreciation as the open-hearth plant, carries a burden of $1.110 per ton of steel produced, using 16 per cent as per above.

The electric furnace consumes electrodes, and a figure of $0.340 per ton of steel is given as a fair average. In the induction type of furnace this would be eliminated, but with an increase in power consumption.

The summary of the situation is given in Table IV.

There are some electric furnaces operating in this country of sufficient capacity to produce facts as to costs for the above comparison, but when an electric furnace operating on castings or special steels produces steel at a cost of approximately $20 per ton of steel, it is not logical to suppose that the same equipment can produce steel at a sufficiently low cost to compete with the open-hearth furnaces in the manufacture of commercial steels. All steel works produce scrap, which must be remelted and made of value, and the amount of

TABLE IV—SUMMARY

Item	Open Hearth	Electric Furnace
Investment, per unit, 200 tons daily capacity	$275,000 0000	$500,000 0000
Interest, depreciation, etc., 16 per cent	0.6100	1.1100
Raw materials (Table I)	14.1034	17.6924
Plant overhead cost and producing labor (Table II)	0.8290	0.8290
Labor in repairs (Table III)	0.0600	0.0600
Electrodes		0.3400
Other overhead	0.0100	0.0100
Total cost per ton of steel	$15.6124	$20.0414

raw materials consumed in the manufacture of steel must remain approximately the same, so that other figures enter into the calculation such as have been tabulated. Accordingly, until the large factor in the cost of making electric furnace steel—the cost of power—is reduced, the electric furnace cannot compete with the open-hearth in the manufacture of steels for rails, structural shapes, merchant bars, etc. In order to do so electrical energy must be produced at a cost lower than $0.001 per kilowatt hour and the present electrical equipment using blast furnace gas cannot do better than $0.007 per kilowatt hour.

Analytical and Laboratory Balances.—CHRISTIAN BECKER, INC., in its recent catalog for balances for chemists and assayers announces the removal of its factory from New Rochelle, N. Y., to Jersey City, N. J., with an office at 92 Reade Street, New York. The catalog contains illustrated descriptions of its principal types of balances with data on capacity, sensitiveness and dimension.

Mercury production in Austria in 1913, according to the report of the Minister of Public Works, amounted to 820 metric tons, valued at $89,208, being an increase of 57.4 tons, but a decrease of $19,145 in value, as compared with the previous year. The entire production came from the Idria mine. Six other mines were then idle.

Production of Zinc Oxide from Low-Grade Carbonate Ore at Leadville

(Editorial Correspondence)

The year 1910 marked for Leadville the beginning of one of those eras of prosperity that make up the varied and interesting history of that remarkable mining district, for in that year the deposits of zinc carbonate were discovered and became the basis of a profitable industry.[1] Ore of shipping grade, say 30 per cent to 35 per cent zinc, was found in large quantities, and thousands of tons were shipped to smelters. It is estimated that during the year 1911 over $3,000,000 worth of zinc in the form of carbonate and silicate was mined and shipped. During the past five years production has continued, and from time to time the smelters have modified their requirements as to grade until at times carbonate ore containing as little as 20 per cent zinc has been marketed.

The limitations of the smelting process, however, prevented the economic treatment of lower grades of carbonate ore which existed in abundance. In Butler's study of the ores[2] he encountered all grades, ranging from practically pure smithsonite (carbonate of zinc) containing about 50 per cent zinc, down to limestone impregnated with zinc, iron and manganese, assaying 15 per cent zinc or less. Smithsonite predominates, and is usually dark reddish or yellowish brown in appearance, soft, porous and earthy. In some compact varieties the mineral is more granular, but without apparent crystalline structure.

Early Proposal of Igneous Concentration

Owing to the physical condition of the zinc carbonate and its intimate association with silica and oxidized forms of iron, the ore is not amenable to ordinary methods of gravity concentration; nor has success been met in recent efforts to adapt some form of flotation to the concentration of these ores. As a consequence, from the time of their discovery until recently, the economic treatment of the low-grade carbonates had not been accomplished. The situation early attracted the attention of metallurgists who realized that the eternal low-grade ore problem would have to be confronted here as elsewhere. Clerc[3] made numerous suggestions for the fire concentration of the ores, with the object of producing a high-grade zinc oxide for subsequent reduction to spelter. In general he voiced the sentiment of other metallurgists who regarded igneous concentration as a logical and feasible process.

In 1914 the Western Zinc Mining & Reducing Co. was organized among Oklahoma oil producers, and a mill was erected at Leadville for the production of zinc oxide from low-grade carbonate ore. The plant was

[1] "From 1860 to 1876 Leadville was a placer gold camp, and little actual mining was attempted, but the discovery of carbonate lead ore in 1874 directed the attention of miners underground. At first only lead and silver (in the form of cerussite and of cerargyrite) were mined, but later extensive deposits of oxidized manganese-iron ores were found; and deeper exploration revealed large bodies of sulphides—mainly galena, sphalerite and pyrite. In 1891 ore chiefly valuable for its gold content was first encountered, and, following the depreciation in the value of silver in 1893, Leadville attracted wide attention as a gold district, although the other metals named were still mined in large quantities. Early in 1910 most of the larger known deposits had been worked out, many of the mines had been abandoned, and it was believed that the great camp with its production of over $380,000,000 was practically exhausted. Then suddenly the mining world was electrified by the announcement that enormous quantities of oxidized zinc minerals had been discovered." Some Recent Developments at Leadville. By G. Montague Butler. *Economic Geology*, Vol. VIII, No. 1, January, 1913. Also *Quarterly*, Colorado School of Mines, April, 1913.

[2] *Ibid.*

[3] F. L. Clerc. The Utilization of the Zinc Carbonates and Silicates of Leadville, Col. *Proceedings* Col. Sci. Soc., Vol. X, pp. 85-98. Also in this journal, A Zinc Retort with a Copper Bottom, August, 1912, p. 463; and The Igneous Concentration of Metallic Values from Mixed Sulphides, April and May, 1914, pp. 250 and 307.

ready for operation in July, 1914, and a short trial run was made just prior to the outbreak of the European war, when the ensuing industrial disturbance in this country caused the company to cease operations. The plant was closed and remained idle until a few months ago, when it was taken over by the Western Zinc Oxide Co., a local organization, under the technical direction of Mr. A. B. Augustine, who originally designed the mill. Operation has now been continuous since.

The Leadville Works

The zinc oxide works at Leadville consists essentially of a furnace, cooling flue and bag house, with the necessary fans for furnace blast and bag house pressure.

FIG. 1—ZINC OXIDE WORKS, LEADVILLE, COLO.

The plant is simple in design and construction, and the process also is simple in principle and theory. Success in practice lies in intelligent supervision, the proper proportioning of furnace charge, blast pressure and air volume, and the education of workmen to a point where they have some conception of what the process is designed to accomplish. As the Leadville plant is situated at an altitude of over 10,000 ft., special consideration had to be given to the volume and pressure of air required for an oxidizing process. Fans, flues and bag house have been designed to meet these requirements, but many details incident to successful operation have had to be determined experimentally.

Wetherill Type of Furnace

The furnace is of the Wetherill type, 65 ft. long, 16 ft. 6 in. wide and 11 ft. high, built of brick and divided into eight double-ended arched fire-boxes extending across the furnace and having a fire-door at each end. The grate area of each double fire-box is 13 ft. 6 in. by 6 ft. 9 in.

The foundation is of concrete and forms eight water-tight compartments beneath the fire-boxes. These compartments are kept filled with water so that the moisture evaporated below the grates may keep the clinker open and porous and aid in the process of oxidation. According to the original design the water compartments were connected by small openings through the transverse walls; but as these openings have sometimes become clogged with cinder falling through the grates, preventing free circulation of water from one compartment to another, a separate water pipe to each compartment has been provided.

The grates are formed of perforated cast-iron plates 11 in. wide, 6 ft. 9 in. long and 1¼ in. thick. The perforations taper from a diameter of ¾ in. on the underside to ⅛ in. on the upper. The ends of the plates rest in the furnace walls and the centers are supported by rails extending across the furnace. The fire-boxes are arched in semi-circular form from the grate level. Above these arches and at right angles to them is the main central arch extending the full length of the furnace and communicating with the combustion chamber at the end.

Extending along the top of the furnace is a 24-in. air main, from which 8-in. pipes conduct air to the pits under the grate of each compartment. The volume of air delivered is regulated by sliding dampers in the 8-in. pipes. A Sturtevant blower supplies 4-oz. blast to the furnace at the rate of 32,000 cu. ft. per minute.

From the combustion chamber a U-shaped cooling flue 4 ft. in diameter and 600 ft. long extends to the bag house. The flue is supported on wooden trusses every 20 ft. It has expansion joints every 50 ft. and small dust hoppers every 10 ft.

Bag House

The bag house contains 288 cotton bags 24 in. in diameter and 26 ft. long, suspended in the usual manner and connected at the bottom with hoppers. The total filtering area is 47,000 sq. ft. The volume of gas handled is about 40,000 cu. ft. per minute, giving a unit filtering area of approximately 1.2 sq. ft. per cubic foot of gas per minute.[4]

The bags are arranged in lateral groups of twenty-four each, with a hopper for every four bags. Each lateral group has a separate connection with the oxide flue, so that the flow can be cut off periodically to shake the bags and clean the hoppers. A National exhaust fan draws the fume from the cooling flue and forces it into the main bag-house conduit and thence to the laterals and bags. The pressure is just sufficient to keep the gases moving through the cooling flue and to prevent back pressure on the furnace.

FIG. 2—PORTION OF COOLING FLUE

[4] This compares with 3.45 sq. ft. per cubic foot of gas per minute in lead smelting practice at Murray, Utah, the area being reduced to 2.5 sq. ft. when one compartment of the bag house is closed. See Notes on Bag Filtration Plants, by Anton Eilers, original communication to the Eighth International Congress of Applied Chemistry; also this journal, Sept. 12, 1912, p. 588.

Preparation of the Ore

The ore treated contains zinc mainly as carbonate, with but little silicate. The latter would not be suitable for the process as it would not decompose readily at the temperature of operation. The average grade is 18 per cent zinc, with a minimum of 16 per cent. The ore is purchased on analysis of a sample secured by taking every tenth shovelful as the lot is unloaded from the car. Lead is an undesirable element, but does not exist in quantities of more than 0.1 per cent in the ores treated.

FIG. 3—ONE SIDE OF EIGHT-COMPARTMENT FURNACE

Ores containing more than 2 per cent to 3 per cent lead are not purchased.

A Jeffrey swing-hammer pulverizer is used for crushing, the product being elevated and screened through a 3/16-in. trommel screen and the oversize returned to the pulverizer. This machine has displaced a Blake crusher and a set of rolls and is giving better satisfaction than the former equipment. The ore varies in moisture content, and some of it is so wet as to give trouble in crushing with jaw breakers and rolls. The swing-hammer machine obviates these difficulties and has shown a capacity of 50 tons in 8 hours, which is ample. The same pulverizer serves to prepare the anthracite coal which is used in the smelting mixture after being crushed to about 5/16-in.

Ore and coal are trammed to the furnace room and dumped on a concrete floor for mixing. A charge for one double-ended furnace compartment consists of 2000 lb. ore and 1100 lb. coal, divided into two equal portions for the fire-boxes on opposite sides of the furnace. Mixing is done by shoveling, the pile being turned over once dry, then wetted to contain about 20 per cent moisture and turned over again. In a larger plant mechanical methods of mixing might be more economical, but at the Leadville works the necessary furnace attendants have ample time to prepare the charge by hand and the method gives satisfaction.

Operation of the Furnace

The eight fire-boxes are charged at both sides simultaneously, and in rotation from No. 1 to No. 8. One hundred pounds of coal is first thrown over the hot grate, 50 lb. from each side, and when ignition has begun the charge of ore and coal is shoveled in and leveled. The blast is reduced in volume at the beginning of the operation and gradually increased as the charge becomes ignited. The furnace foreman regulates the blast and rabbles the charge occasionally to prevent the formation of blow holes and insure a bed of uniform density. In six or seven hours the zinc is driven out of the charge. The sinter is then withdrawn and taken to the dump, and a new charge added. At this rate of operation the furnace has a capacity of 30 tons of ore in 24 hours.

Under the present method of operating the sinter carries from 2 per cent to 4 per cent zinc, which is an improvement over earlier practice, resulting from a better proportioning of the slag-forming elements in the ore. The ores vary in iron and silica content, and are mixed to give a nearly neutral sinter, with iron slightly in excess owing to the greater abundance of that element.

The furnace temperature is about 1000 deg. C., but by the time the gases have passed through the long cooling flue they enter the bag house at a temperature of about 140 deg. C. Cooling by radiation is augmented by the admission of air at a number of the hoppers near the bag-house end of the flue.

The bags are shaken by hand every two hours and the hoppers are emptied once in 24 hours. The product is a high-grade white zinc oxide, containing 76-77 per cent zinc, equivalent to 95-96 per cent zinc oxide. It contains also from 1 to 1½ per cent lead, and is suitable for use as a pigment without reburning. The ratio of concentration is between 4 and 5 to 1, and production amounts to about 6 tons of oxide per day.

As matters now stand the Leadville works should become an economic factor in the mining and treatment of low-grade zinc carbonate ores. Time and experience have served to remove many of the difficulties encountered in the trial run of a year ago. Bag-house capacity is apparently ample, and slag and fume losses have been reduced to a minimum. The labor problem grows less acute as the men become educated in the details of operation, and the process is now working to the satisfaction of its promoters. The plant is favorably located with regard to transportation facilities, ore and fuel supply and power, and apparently no unfavorable conditions now exist to prevent continued success.

Antimony has been found in many places in Mexico, especially in Durango, Sonora and Oaxaca, and relatively small amounts of ore have been shipped to the United States for smelting; however, the Catorce deposits have been the best producers for the last 20 years. The mining ores run from 25 to 70 per cent pure antimony. Antimony appears in many ores treated at the lead smelter in San Luis Potosi, but its presence in these ores is deleterious, and in the bullion it is regarded as an impurity.

The vapor pressure of arsenic trioxide is the subject of Technical Paper No. 81, of the U. S. Bureau of Mines. The authors are H. V. Welch and L. H. Duschak. The paper embodies the results of an investigation undertaken with a view to the proper design and control of equipment for recovering arsenic from smelter gases.

Chemical Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

(*Concluded from page* 543)

The Removal of the Sulphur

Sulphur may be introduced into the furnace by any of the raw materials, the fuel, the ore, or the flux, their responsibility for its introduction being in the order given.

The flux generally contains only traces of sulphur, but one case came under my observation in which the management of a charcoal furnace was greatly disturbed and equally puzzled to find the sulphur in their iron too high with no apparent reason for its being so. Analyses of the ore and then of the charcoal showing nothing out of ordinary, they finally analyzed the limestone and found enough sulphur to account for all the trouble. I think the amount was about 0.3 per cent, which was sufficient to spoil charcoal iron, because the slag on which it was made was so acid as to leave in the iron a considerable proportion of the sulphur in the charge.

Most of the ores of the Lake Superior region are very free from sulphur, although several of these on the Menominee range contain as much as two or three-tenths. The ores of the Virginia and Alabama iron districts contain in general only the faintest traces of sulphur, as do most of those of the East, but some of the magnetites of New Jersey and Eastern Pennsylvania are high in sulphur, in particular, the ore from the Cornwall mine near Lebanon, Pa., the largest and most famous single mine in the East, which has been worked continuously since revolutionary times; it contains on the average about 2 to 3 per cent of sulphur and cannot ordinarily be used in the furnace without giving it a preliminary roast, which reduces the sulphur in unconcentrated ore to between 0.5 and 1 per cent. A large proportion of this ore is now crushed fine and magnetically concentrated, after which the fine concentrates are nodulized in a rotary kiln, and this in good practice reduces the sulphur to 0.05 per cent or under. Some of the magnetites of Canada are also high in sulphur, running 3 to 4 per cent in their native condition, and these are either crushed fine, concentrated and agglomerated, or treated by roasting, which reduces the sulphur to within permissible limits for furnace use. In general if an ore is rich and pure enough in other respects to be worth the treatment it can be so roasted as to lower the sulphur within easily usable limits.

SULPHUR IN FUEL

Charcoal is free of sulphur to a far greater extent than any other furnace fuel, but varies within quite wide limits. Charcoal from hardwood, exclusive of its bark, nearly always contains well under 0.1 per cent and even down to 0.02 or 0.03 per cent, while the bark may simultaneously contain 0.2 or 0.3 per cent or even more sulphur; but the bark is such a small proportion of the whole that good hardwood charcoal probably averages under 0.1 per cent of the whole.

This small amount is largely absorbed even by the most acid slag, and only a small quantity enters the iron, under 0.02 with good raw materials, in ordinary practice.

This absence of sulphur and the consequent absence of need to run the furnace for desulphurization constitute the fundamental difference between charcoal and coke or anthracite practice and the irons resulting from them.

Coke contains all the way from 0.6 per cent to 2 per cent sulphur, which is present in two forms, ferric and ferrous sulphide, FeS_2 and FeS, and vegetable compounds.

The sulphur combined with iron occurs in the form of pyrite FeS_2 in the coal, but the heat of the coking operation drives off one molecule of sulphur from some of the pyrite and leaves it in the form of FeS in the coke, so that coke makers have a rule for general use that the diminution of sulphur is just about the same as the loss of weight in coking, so that the percentage of sulphur in coke is about the same as that of the coal from which it is made. I believe that the classification of coke into good and bad as regards sulphur in the minds of most furnacemen is based on whether it is above or below 1 per cent. The original Connellsville coke had only about this and the New River and Pocohontas considerably less, but the sulphur in some of the Western Pennsylvania fields outside the Connellsville basin are higher and much coke is now used running 1.25 per cent and upward in sulphur.

I have known of a case where a plant ran for a considerable period on coke of nearly 3 per cent sulphur, but as the manager said, "I had to disregard coke consumption in order to make good iron." In another case a plant was run for a term of years on coke of 1.75 per cent sulphur.

As the sulphur specifications for steel mill irons are "under 0.06 per cent," and for all merchant iron "0.05 per cent and under," or in some cases "0.03 per cent and under," it is obvious that nearly all the sulphur brought in by the raw materials must be eliminated.

The method by which this is done consists principally, if not solely, in carrying the sulphur off with the slag as calcium sulphide CaS, there being no considerable portion of the sulphur carried off by the gas. There may be volatilization of sulphur in the hearth, but if so, the vapor formed is caught by the slag as it rises through the bosh and brought back into the hearth, so that the net effect of such an action is nil. The existence of such a condition has never been investigated as far as I know. Sulphur is always thrown off by a hot coke-furnace slag, in many cases in heavy volume, but this may be due to the oxidation of CaS of the slag to CaO and SO_2 with the oxygen of the air, a reaction which could not take place in the reducing atmosphere of the hearth, so that this evolution of sulphur from slag in air is no proof of a similar condition in the furnace.

The reactions by which calcium sulphide is formed are not very definitely known, but involve the reducing action of carbon to assist the reduction of the calcium from the oxide to the sulphide presumably by reactions somewhat as follows:

$$FeS + CaO + C = Fe + CaS + CO$$

This is the reaction given by Prof. H. M. Howe in his "Iron, Steel and Other Alloys," and is probably correct in principle if not exact in detail. The sulphur which is present as an organic compound is presumably carried off in a similar way, but nothing definite is known about the details of the reaction. It seems certain, however, that the sulphur cannot reduce lime to calcium sulphide without the assistance of the reducing action of the carbon. As a matter of fact the reactions are probably not so simple as indicated, since the silica exerts a powerful attraction for the lime and there must be enough of the latter present to satisfy the silica before much sulphur is removed.

We encounter here for the first time the fact which should be impressed upon the mind of every student of this subject and which is too little realized or taught in metallurgy:

The chemistry of the blast furnace is not a chemistry of definite atomic proportions but it is a chemistry of infinitely varying balances among conflicting tendencies.

A homely illustration is that if you place a heavy book upon the seat of a rocking chair the chair will take up a certain position; if you push the book back the chair will tip back and if you pull the book forward the chair will tip forward, its motion being roughly proportional to the movement of the book. If the rule of definite atomic proportions held the rocker of the chair would consist of only two or three straight sections of definite length and making considerable angles with each other, and the book could be removed through considerable distances without affecting the position of the chair, then when it did move it would rock instantly from one straight section to the next and remain at rest in that until the book had been shifted through another considerable range.

Nothing could be further from the facts of furnace operation than the last illustration, nothing be more like than the first. Each change of conditions sufficiently large not to be masked by the continual variations of operation produces its proportional effect, and these effects shade from one to the other by imperceptible gradations. It is, I think, this law which scientists have tried to capture and brand as "The Phase Rule." It is perhaps the misfortune of my generation that we had passed our student days when this rule was enunciated to the public and so did not grasp the new conception which it tries to codify, so that the simple relations which are used to illustrate the workings of the phase rule do not seem to need or receive additional light from it, and the more difficult ones whose explanation is sought by its assistance are made the harder for us to understand by the introduction of its difficult terminology. To another generation trained to think in this terminology from their collegiate years it will, we may hope, prove a benefit, but for the purposes of this work plain statements of fact with such homely illustrations as the above must suffice.

Returning now to the subject of desulphurization, the condition surrounding it and the number of substances involved in the operation is too great to permit its investigation without a vast amount of experimental work and overcoming many difficulties. We know, however, as the result of observations on operation four factors upon which desulphurization depends: First, the relative excess of bases over acids in the slag (positive); second, the temperature of the slag (positive); third, the fluidity of the slag (positive); fourth, the concentration of sulphur in the slag (negative).

The bearing and results of these laws may be more properly discussed under the head of furnace operation and need not be further considered here.

The Reduction of Silicon, Phosphorus, and Manganese

These elements are all more difficult to reduce from their oxides than iron and therefore it should theoretically be possible to run the furnace so that iron would be reduced but none of these impurities. But as a matter of fact it is not possible to do so; if they are present in the charge they will be found in the iron to some extent. We can vary this extent very much in the case of two of them, but even here we cannot exclude them altogether under practical operating conditions, if at all.

This is for the reason that iron exercises a solvent action upon all three elements and forms a definite compound with at least one of them, and probably the others also. The difference between a physical solution like that of caustic soda in water and a chemical combination like that of caustic soda with hydrochloride acid is not so great or at least so readily distinguishable at the high temperatures in the health of the furnace, and I do not feel qualified to distinguish between them in all cases. But it seems likely that manganese forms with iron only a solution or perhaps with the carbon in the iron a double carbide, the silicon acts as if formed silicide and a solution of this silicide in the iron, while phosphorus is known to form two or three definite phosphides, and solutions of some of these in iron.

Without attempting to pass definitely upon the question of whether the iron merely dissolves the silicon and manganese or really combines with them, we know that it has a considerable affinity for all three of these elements, and this fact has a strong influence in their reduction from the oxide to the elemental condition in which they are taken up by the iron. This is important because all of them are more difficult to reduce than iron requiring a higher temperature and a greater quantity of heat per unit of element reduced than does iron, and if the reducing action were not assisted by the affinity of iron for these substances in their elemental condition it is probable that they would not be reduced at all or in much less degree than they are.

The case is analogous to that of copper smelting which utilizes the power of copper as a "catcher" for silver and gold. The ores of these metals are charged into the copper furnace and a very large proportion of their values is caught by the copper matte, from which they are subsequently recovered by electrolytic refining; but if the copper were not there to act as a catcher these values would largely be lost in the slag and the fumes.

It is believed that all three elements under discussion are deduced by solid carbon and not to any extent by CO.

Phosphorus is more completely reduced than either of the other two. This may be because of its stronger affinity for iron rather than to greater inherent reducibility, and practically all of this element present in the charge passes into the iron unless the furnace is working "cold" with a scouring slag, when as much as 10 per cent of it may, according to Sir Lothian Bell, pass into the slag. From my own observation, I should say that even a considerably greater percentage of it could be eliminated in this way, but as this never happens except when the furnace is working very badly it is a matter of no industrial or commercial importance, and I have never investigated it.

It is stated in Sexton and Primrose's "Metallurgy of Iron and Steel," pp. 61 and 62, that phosphorus is not reduced at all by incandescent carbon except in the presence of silicon in excess. The phosphorus is generally present in the ore as tricalcium-phosphate and the reaction is said to take place according to the equation:

$$Ca_3P_2O_8 + 3SiO_2 + 5C + Fe = 3CaOSiO_2 + 5CO + FeP_2$$

Silicon is always present in excess in the charge and so the phosphorus can always be reduced even if this be a necessary condition. In the absence of any experimental data on the reduction of phosphorus in a furnace working without silica in the charge it is really more or less an academic, rather than a practical question whether this is a necessary condition or not. But I incline to the belief that while incandescent carbon alone may be unable to reduce phosphorus from the calcium phosphate, incandescent carbon in the presence of molten iron in excess might be able to cause the reaction to take place even in the absence of the silica; this is, of course, equivalent in a rough way to saying that the affinity of iron for phosphorus is probably as great as that of lime for silica so that the occurrence of the former reaction would compensate for the absence of the latter, but for practical purposes this is merely speculative.

The percentage of the total manganese changed which is forced into the iron depends upon the temperature at which the furnace is worked and the basicisity of the slag, from a half to two-thirds of the whole amount charged will pass into the iron in ordinary coke practice and less than this in good charcoal practice because those furnaces are worked both colder and with a more acid slag, though charcoal furnaces *can* be worked to throw as great a percent into the iron as can be done with coke. A part of the manganese is lost in the slag and a part by vaporization in the hearth, the latter can be plainly seen at furnaces making ferromanganese passing out the stacks of the stoves and boilers as a very heavy yellow fume.

The relative amounts lost in these two ways depend on the hearth temperature and the composition of the slag. Raising the hearth temperature tends to increase the vaporization loss and to diminish the slag loss while acid slag increases the slag loss rapidly without much effect on the vaporization loss. Cases are on record of unsuccessful attempts to make ferromanganese in which nearly all the manganese charged passed out into the slag, only an insignificant amount passing into the metal.

Silicon is generally present in the charge in far greater quantity than is needed to supply the percentage desired in the iron. Generally the composition of the raw materials is such as to produce this condition whether we will or not, and if it is not so the furnaceman usually produces it by adding a silicious ore to the charge as it is easier to get the silicon desired into the iron when a superabundance is present than it is to obtain it by robbing the slag of the silicon it needs. In coke practice the silicon thrown into the iron is commonly less than 20 per cent of the silicon of the total silicon charged. On the other hand, I have run a charcoal furnace on rich low-silica ore and made high silicon iron, about 3 per cent, which required more than half the silica charged for its production, but this is not good practice.

It is stated by Sexton and Primrose (*Op. cit.*) that silicon is not reduced by carbon at temperatures below those of the electric arc which means that the affinity it has for iron is strong enough to make up the deficiency in the reducing power of carbon and so the silicon is reduced not to the elemental state, but the state of silicide of iron. This is borne out by the limitations of the manufacture of ferrosilicon in the blast furnace. This material containing as high as 13 per cent Si ordinarily, and higher occasionally, is regularly produced in blast furnaces using very high blast temperatures and a large quantity of fuel per ton of product, but when material containing more silicon than this is desired it is necessary to go to the electric furnace which is quite without those limitations of temperature under which the blast furnace suffers, and in that apparatus it is perfectly possible to produce a material containing from 50 per cent to 80 per cent Si, or higher for special purposes. This is probably explained by the fact that when the iron reaches say 15 per cent Si it is so nearly saturated for this element that it does not exercise any considerable affinity for any further amount and reduction of silicon accordingly ceases.

Since the above was written I have been informed by Prof. J. W. Richards that silica begins to be reduced by carbon at 2750 deg. Fahr. and is reduced quite freely at 3250 deg. Fahr. Whatever may be the conditions as to silica alone the facts of practice are as above stated.

It seems likely that all these elements are reduced on the surface of the incandescent coke in a way exactly similar to the reduction of litharge to lead on the surface of a piece of chemical by blowing on it with a blow pipe. The conditions in the furnace are exactly the same on a large scale. As these elements are reduced the trickling iron running down over the surface of the coke on which they are produced is immediately at hand to take them up.

It has several times been suggested that the silicon of the iron came from the silica of the coke. This suggestion has much to recommend it and is probably largely correct for ordinary conditions, but in the manufacture of forrosilicon in the blast furnace in which the silicon goes up as high as 13 per cent it is obvious that this cannot all come from the coke since ordinary coke contains less than 7 per cent silica corresponding only to about 3 per cent of silicon. This proves conclusively that the silica of the coke ash is not the only source of silicon and indicates the probability here as in so many other cases that the course followed is a compromise between two possible extremes, a balance between opposing influences. The reaction according to which this reduction takes place is then of the form:

$$yFe + SiO_2 + 2C = Fe_ySi + 2CO.$$

SLAG

The impurities of the fuel and of the ore must be eliminated from the furnace. In the early days this was probably done in the same way as taking the clinker out of a domestic fire by prying the clinker up from the bottom and raking it out, but in a furnace over thirty feet in height, which the early furnaces soon came to be, it obviously could not be taken out the top and an opening was provided in the hearth with a fore hearth in front of it, through which access could be had to the inside of the furnace by removing the heavy lid of the fore hearth. This was only done after cast when the blast was off, as at any other time the gas formed in the hearth would have blown out the opening and made work impossible in the vicinity.

Gradually it came to be realized that the slag could be made fusible by the addition of "flux" and that when this was done it was not so necessary to open up the front and "work her down," so that practice declined and died out, but not so many years ago as might be thought, since I can distinctly remember as a very small boy seeing a jib crane, hung from the stone pier of the front arch of the furnace, to the chain of which the keepers hung in turn a huge poker and a gigantic shovel, as I recollect it about two feet square, and perhaps some other tools which were laboriously operated by two or three men who were not as economical of their strength as is now customary.

This was a charcoal furnace, but I am informed that the same practice was retained at the anthracite furnaces perhaps even to a later date.

The early furnaces always used charcoal fuel in which the percentage of ash is small and that present largely lime and alkali while sulphur is almost absent. For these reasons lime was little needed and its use developed slowly, but when soft coal and anthracite came into use, with a much larger amount of ash and sulphur, the latter requiring a relatively basic slag to keep it out of the iron, the use of flux came into regular use.

The principal impurity in both ore and all mineral fuel is silica. Its importance comes from two sources; first, it is generally present in much larger quantity than any other substance, and second, it is a much more active acid, if not the only acid of importance in common practice.

Next in quantity and importance comes alumina, which is very weak chemically, practically neither acid

nor basic, but has a powerful effect on the physical characteristics of the slag.

These combine with mineral bases and the compounds so formed are far more fusible than any of the components separately. For instance, silica melts about 3180 deg. Fahr. and lime alone is infusible even in the oxyhydrogen blow pipe, but these two form compounds which melt about 2100 deg. Fahr.

Advantage is taken of this fact to convert the impurities of the charge into a fusible slag which runs from the furnace easily by adding mineral bases to the charge, even in charcoal practice where sulphur is almost entirely absent, and in coke practice the addition of lime is carried much further so as to render the slag basic enough to fix the sulphur and carry it out of the furnace.

In practice only two bases are ever used, lime and magnesia. This is for two reasons; first, they occur in the greatest abundance in nature, far exceeding all the other alkalies or alkaline earths put together, and in massive geological formations close to the earth's surfaces so that they can be cheaply obtained by quarrying, and second, because they are among the most powerful of all the bases chemically, particularly lime, which will even replace caustic soda in combining with some acids.

Lime alone is often used as flux, but never magnesia. This for two reasons; first, that lime carbonate, which contains only insignificant quantities of magnesium carbonate, occurs in vast quantities in nature, but the reverse is so seldom true as to make the latter compound many times more expensive than limestone; second, the chemical activity of lime is much greater than that of magnesia. It was claimed by Sir Lothian Bell that magnesia was worthless for purposes of desulphurization; experience has proven this not to be true when both lime and magnesia are used together and whether it would be true if magnesia alone were used for flux is a purely academic question since commercial considerations prevent its use for that purpose.

Much limestone contains magnesium carbonate in quantities varying from a trace up to true dolomite, the double carbonate of lime and magnesia, $CaO,Mgo(CO_2)_2$ in which when decarborated the bases are present in the proportion of 41.7 and 58.3 per cent owing to the difference in the atomic weights of Ca and Mg. Dolomite occurs in nature in great quantities also as does dolomitic limestone and these are used as flue either alone or in conjunction with limestone, according to considerations which may be more appropriately discussed under the head of operation.

The combination of those bases with the silica of the charge forms the silicates of lime and magnesia which constitute in all cases more than half the total slag volume and this acts as a solvent for many other ingredients of which the alumina, in my judgment, is one; the principal one in quantity, next to the basic silicates themselves, varying from 7 to 15 per cent in ordinary coke practice but going as high as 35 per cent in certain special cases. The ingredient next in quantity in coke practice is calcium sulphide CaS, ranging from 2 to 5 per cent, but in normal practice from 3 to 4 per cent.

There is always present a certain amount of iron in the form of FeO. This varies from a mere trace in a white cinder made in a hot-working furnace to several per cent in bad working, but under 1.0 per cent in any normal working furnace. Manganese oxide MnO is present in quantities depending on the amount of manganese in the charge, in ordinary irons running under 1 per cent in manganese, the MnO in the slag should be under 0.5 per cent and from this down to a trace. On the other hand when high-manganese irons, spiegel and ferromanganese are being made there are always several per cent of MnO in the slag, even in best practice.

In general the rule that one-third of the manganese charged will go into the slag even if the furnace be operated to throw as much as possible of it into the iron, will define the minimum amount to be expected in the slag, and this may be increased up to a large proportion of the whole amount charged by different furnace operation.

Titanium

Some ores and fuels contain other elements in small quantities which go into the slag or into the iron in varying proportions. One of the most common of these is titanium, which occurs in some cokes and in many ores in amounts varying from a trace up to 15 or 20 per cent, in the form of titanic acid TiO_2

This is extremely irreducible and infusible and its presence complicates the operation of the furnace materially, and for a very unusual reason; this is its affinity for nitrogen since with this and cyanogen it forms a cyano-nitride of titanium. This is highly infusible and does not dissolve in the slag, so remains in the hearth, and gradually fills it up to such a point that the furnace can no longer function properly. It was long held that the presence of a small quantity of this material rendered ore unfit for use in the blast furnace, but the whole question has recently been attacked anew and methods will probably be found whereby it can be fluxed. There is much reason to believe that the former verdict against it was on insufficient grounds.

In some cases the principal impurity in the ore is lime instead of silica, but there is seldom a sufficient excess to do more than flux the ash of the coke. When there is it is not customary to add silica by itself to the charge, but to use a portion of some other commercially available ore with an excess of silica, thereby avoiding the addition of barren material, either acid or basic, to the charge and so killing two birds with one stone.

The red hematites of Alabama and the Minette ores of Lorain and Luxembourg are the two most notable cases of ores of this kind.

The reaction between silica and lime is an exothermic one so that when they are heated to a temperature high enough to permit reaction between them the reaction goes forward more rapidly on account of the heat evolved. At the same time the quantity of heat evolved in this reaction is not comparable with that in many others, being only about 300 B.t.u. per lb. of compound produced as against several thousand in some other reaction. Perhaps for this reason the resulting product differs less in its properties from those of its component substances and acts more like a solution than a chemical compound as compared with those substances which react more violently together.

It is generally believed that the formation temperature of slags is higher than the temperature of fusion so that if lime and silica be heated together they have to be raised to a higher temperature before combining than the resulting slag would require to remelt it.

This is a more or less obvious corollary to the fact that the melting temperatures of the ingredient are higher than that of the compound. It has been found also that the fineness of grinding and the intimacy of contact of the particles have a powerful effect on the temperature of formation which is likewise to be expected for the same cause.

These are facts which are sometimes of capital importance in understanding the operation of the furnace, and we shall have occasion to return to them in discussing that subject.

THE FORMATION OF CYANIDES

This is a subject concerning which not much is known.

The intimate contact of the nitrogen of the blast with the incandescent coke near the tuyeres in an absolutely reducing atmosphere furnishes the condition of high temperature necessary to carry out the highly endothermic reaction between those two elements while there is always present a certain amount of alkali from the ash of the coke with which the cyanogen can unite to form alkaline cyanides, the presence of which around the hearth and bosh has often been noticed.

Several years ago an attempt was made to draw these cyanides from inside of the bosh and turn them to commercial use and while this attempt met some degree of technical success it was not continued and it is safe to say that commercially it was unsuccessful.

It has been suggested that these cyanides played an important part in the final reduction of the ore and it is entirely possible that this is so since cyanogen is a powerful reducing agent and most of the cyanides formed in the hearth must be volatilized and rise through the charge with the gas column until they are either broken up or condensed and carried back by the charge. But so far as I know no critical investigation of this subject has ever been carried on so that little of value is known about it.

Sir Lothian Bell investigated the subject more thoroughly than any one else of whom I have knowledge; his results were published in his "Chemical Phenomena of Iron Smelting," but did not go further than to establish the fact that cyanide occurred in considerable quantities in the hearth and bosh of the furnace.

CALCIUM CARBIDE

All the literature dealing with calcium carbide states that its temperature of formation is so high that this can only be reached in the electric furnace, but in tearing out the hearths of furnaces blown out for repairs and wetting down the material left in them, I have several times noticed the smell of acetylene so plainly that it was unmistakable, and considering that lumps of lime are often found in the hearth under such conditions, when the furnace has been running on a basic slag and that this lime must have come down in contact with incandescent coke at a very high temperature, it does not seem unlikely that a certain amount of calcium carbide should form. It is impossible to say to what extent this reaction takes place, but it has a certain interest in view of the calcium carbide theory of steel purification in the electric furnace, which is receiving quite general acceptance, and as showing that reactions which are commonly stated to take place only at the temperature of the electric arc, do really occur in a limited way at lower temperatures when the conditions are favorable, furnishing a further illustration of the general law of varying equilibrium between contending forces depending on the conditions of temperature, chemical concentration, etc.

There are probably many, if not many hundreds of other reactions, which go on in the hearth under the condition of extremely high temperatures and intensely reducing atmosphere which prevail there, but the above are the principal ones necessary to an understanding of the action of the blast furnace.

The Hollinger mill, Porcupine, Canada, is now treating Acme ore, twenty stamps being in operation. The other half of the new 40-stamp unit should now be in operation. When the entire capacity is being utilized, about 900 tons of Hollinger ore and 500 tons of Acme ore will be handled daily.

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Sulphate of Ammonia Production in 1914.—From a bulletin issued by the American Coal Products Company we learn that European statistics for 1914 are available only to a limited extent. The estimate of the world's output may be hazarded at 1,300,000 to 1,350,000 metric tons, as against 1,409,000 in 1913.

As regards the prospects for 1915 it is quite probable that an increase may result from the demand for explosives. For this benzol, toluol and ammonia are required and by-product recovery has been stimulated.

"The by-product coke oven still continues to be the main source of ammonia recovery, and the one that promises the most extension in the immediate future, coal gas works standing next in total output, though much greater in number and more widely distributed geographically. The by-product recovery gas producer, the shale oil distillation process, and the English blast furnaces using splint coal, are also responsible for a certain amount annually. Some is also obtained from the carbonization of bones, and from peat, there being two Italian plants reported as operating on this material.

"The methods by which atmospheric nitrogen is transformed into ammonia, viz., the synthetic process of Haber and La Rossignol, and the manufacture of calcium cyanamid, afterwards treated to liberate ammonia, appear to have been extensively pursued in Germany, because of the needs of war and agriculture. So far the Haber process has not been introduced elsewhere, but the production of ammonia from cyanamid has been carried on in Germany and Italy and to a limited extent elsewhere.

"It is both interesting and significant to note in this connection that a bill has recently been introduced in the German Federal Council to create a nitrogen monopoly in Germany extending to 1922.

"Commercially the season of 1914-15 was one of hope deferred rather than of fulfillment. The unfavorable prospects at the close of 1913 were adequately realized in a market that sagged continually throughout the first half of 1914. The outbreak of war, coming in the quiet season, did not change matters very much either way. The embargo placed on sulphate of ammonia exports by the German government in September, which might have operated favorably on English prices, was in effect neutralized by the unfavorable cotton situation in the United States and the increased risk and cost of ocean transport. Toward the close of 1914 more favorable conditions began to prevail and prices began to have an upward tendency. The monthly English quotations, however, have averaged from 25 to 50 shillings below those of the previous year, and the average for the year is 40 shillings lower."

The production of England was 426,413 gross tons, about 6200 tons less than 1913. The cause of the reduction is the war, the gas works having lost the most heavily. The consumption was 106,000 tons and exports 313,877 tons or nearly 12,000 tons less than 1913. There are no figures on German production, but so far as can be judged by trade conditions, there was an increase during the first half of the year. The total sales for home use by the Deutsche Ammoniak-Verkaufs-Vereinigung was 321,404 tons. Exports for the year were 75,868 metric tons and imports 34,628 metric tons. In the United States 183,000 net tons of sulphate were produced, being 12,000 tons less than 1913. This reduction came mostly in the last half of the year and was due to the influence of the war on the iron and

steel trade. The consumption was 272,000 tons as against 262,000 tons in 1913, showing an increase even though production decreased. The possible yearly recovery from coal now carbonized is 700,000 tons, showing that there is an enormous production available from coke, provided that it was all made in by-product ovens.

The Coking of Coal at Low Temperatures is the title of Bulletin No. 79 of the University of Illinois Engineering Experiment Station, the authors being S. W. PARR and H. L. OLIN. (Price, twenty-five cents.) This bulletin describes experiments which were a continuation of the work described in Bulletin 60, the later experiments being conducted on a larger scale. The object of the experiments was to test the coking properties of coals from different sections in Illinois, at temperatures between 400 and 500 deg. C., and to test the resulting by-products. The apparatus used in the coking experiments is shown in Fig. 1 in which *A* is a boiler-plate

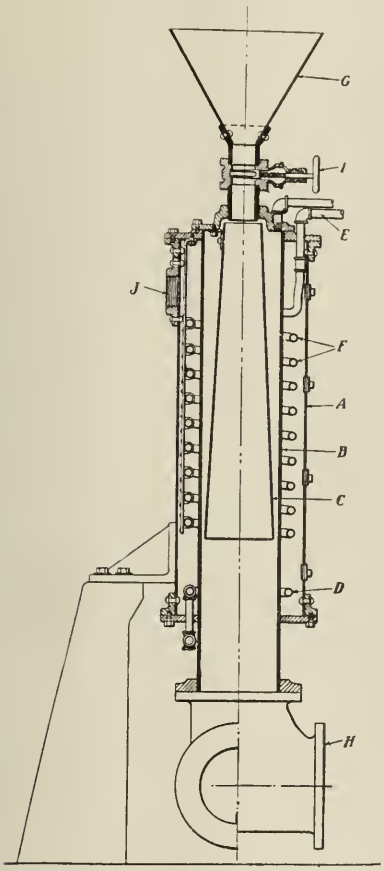


FIG. 1—CROSS-SECTION OF APPARATUS FOR LOW TEMPERATURE COAL DISTILLATION

shell lined with asbestos, *B* is another shell which forms the coking chamber and contains the light sheet iron cone *C* which is perforated. In order to obtain a non-oxidizing atmosphere steam was admitted at *E*. The non-oxidizing atmosphere was found to give better coking results as explained in Bulletin No. 60. The heat was supplied at burner *D* from gas and air mains, and the charge of crushed coal was fed into *G*. The coked residue was removed through *H*, and gases of combustion escaped through *J*. The distillates were conducted to a condenser, and the tars were passed through a water-sealed exit at the bottom.

It was found that better cokes were produced in some cases where fine coke dust was added to the charge, sometimes as much as 100 per cent being required. The coke from one of the experiments was tested in an Otto gas producer and the gas was found to contain negligible quantities of tar and would therefore be useful in internal combustion engines. The efficiencies of the producer compared favorably with those when using anthracite for which the producer was ordinarily used. Heavy hydro-carbons were removed to such an extent that the coke was found to be adapted to household use; being clean in handling and burning. On account of the low temperature the coke had from 18 to 22 per cent of volatile matter remaining, but since it was heated above 400 deg. no tar constituents should remain. This was confirmed by the gas producer tests.

The tar products were next examined and the following results were noted: Average specific gravity 1.069, 18 per cent low-boiling distillate passing over at 210 deg. pitch residue 30 per cent and free from precipitated carbon, high percentage of tar acids making the tar adaptable to wood preservation. Ten per cent of the crude tar was low-boiling distillate free from tar acids and available for use in internal combustion engines. Napthalene was absent and the free carbon in the crude tar was less than 2 per cent.

These experiments were not intended to devise a commercial apparatus but merely to point out in what direction work might be carried on to make a commercial process. The main point brought out in regard to the tar is that low temperatures tend to decrease the amount of comparatively valueless products such as naphthalene and heavy pitch and to increase the production of the lighted and more valuable hydro-carbons.

The Chemical Industries of Austria-Hungary and the War.—In *Chemiker-Zeitung*, July 7, 1915. ED. DONATH and G. ULRICH give an outline of the chemical industries in Austria-Hungary and the war's effect on them. The chief influence hindering normal production has been the inability to carry on commerce, and the lack of raw materials. The labor shortage has also had its effect. The coal industry was severely hampered at the beginning of the war partly from lack of labor and partly from want of means of transportation. It has improved, however, and is now operating at about three-fourths capacity. Inquiries for coal are numerous, but inquiries for coke are very small. There is, however, a big demand for coke by-products and Austria is making big demands on Prussian-Silesian coke production. Germany and Austria are rich in coal lands, Germany in bituminous coal and Austria in lignite, having shipped 7,000,000 tons to Germany in 1913, in which year Austria imported from Germany 12,152,500 tons coal and 1,051,670 tons of coke.

The production of oxygen has decreased since the beginning of the war. In normal times, there are six companies in Austria producing 6 to 7,000,000 cu. meters per year. For sulphuric acid manufacture Austria-Hungary has a plentiful supply of raw material, especially in the rich copper minerals in upper Hungary. Plentiful quantities of salt are available from Galicia and the Austrian Alps. The alkali industries can scarcely fill the needs for alkali salts. In general it can be said that the inorganic chemical industry has improved since its setback at the beginning of the war and new foundations are being established.

In the important fertilizer industry, the suppression of imports of Chile saltpetre must in time exhaust the supply on hand. The production of ammonium sulphate, the most powerful nitrogen fertilizer, is below other years, because the smelting furnaces which use coke are not running to full capacity. The necessity of keeping up a good production of coke for nitrogen by-products has been impressed upon the people by several authors and the Austrian Chemical Society has formed a committee consisting of representatives of different

industries to take up this question. In Norway calcium nitrate, nitric acid, sodium nitrate and ammonium nitrate are made by the Birkeland-Eyde and Schönherr furnaces and ammonia is made in Arendal by the Serpek process.

The great glass and glassware industry has decreased its output through lack of coal and means of transportation. Raw materials for the clay industries are plentiful. The cement industry has been very much affected, there being used in August and September, 1914, only about 40 per cent of the normal demand. The brick industry and steel and rolling mills were also hard hit.

In 1913 the Austro-Hungarian iron and steel industry was producing considerably under normal capacity; this is an international condition, which the Balkan War helped to create. Lately an improvement has taken place in this and the non-ferrous industry, since imports of metals were stopped, and consequently a larger production of copper, lead, zinc, etc., became necessary. There are many mines in Austria which are rich enough to keep up the normal requirements.

Iron and Steel

Electrical Steel by the Acid Process.—In an article on this subject in *Stahl and Eisen*, 1914, No. 3 Albert Müller discusses experiments on the production of acid-electric steel, and shows the advantages and disadvantages of the process as compared with the basic method. A three-ton Girod furnace was used with a hearth made of the following mixture: 80 per cent silica brick, 6 per cent fireproof clay, and 14 per cent tar as a binder. The walls were made of silica brick. The extent to which the lining is attacked in an acid and basic furnace is shown in the analyses given in Table I.

Table I—Composition of Acid and Basic Furnace Materials

	Electric Furnace Hearth—Before Melting		Electric Furnace Hearth—After 27 Heats,	Acid Furnace Walls	
Component	Basic, Per Cent	Acid, Per Cent	Acid, Per Cent	Before Melting, Per Cent	After 27 Heats, Per Cent
SiO_2	5,72	80,50	64,60	95,30	83,50
Ca O	46,50	4,30	12,90	1,85	3,55
Mg O	27,60	1,91	2,90	Spur	0,65
Al_2O_3	1,46	3,08	2,65	0,58	0,97
Fe_2O_3	1,85	0,38	0,43	0,57	4,50
Fe O	0,99	1,16	1,93	0,26	3,65
Mn O	0,40	0,27	12,05	0,19	2,36
P_2O_5	0,09	0,02	0,02	0,08	0,08
C	8,60	7,75	1,20	....	....
Ignition loss	14,35	7,80	....	....	....

Table I gives a comparison of the composition of hearth and walls of basic and acid furnaces, before and after melting, and shows clearly the change in silica content due to the charge and also the change in metallic oxides. It will be noticed that the carbon content of the hearth is reduced from 7.75 to 1.20 per cent in the acid furnace. In the basic furnace the carbon does not react with the charge. In the acid furnace, however, it plays an important part in the reduction of silica. In some cases this reduction is too great in the first melt. The reduction of silica by which the silicon content of the metal bath is increased in an acid furnace may be divided into four phases.

1. Reduction from charge, hearth, and walls at normal temperature and conditions. In this case it is mostly reduced from the hearth and walls.

2. Reduction by raising silica content of the slag by introducing sand.

3. Reduction by raising the temperature of the slag. This is accomplished by arcing.

4. Reduction by carbon, according to the formula $2C + SiO_2 = Si + 2CO$.

All of these reactions are more energetic as the temperature of the slag and steel bath is raised. The silica reduction is much stronger in a newly lined furnace. The large amount of silicon withdrawn from the lining and slag makes it unecessary to add ferrosilicon for the deoxidation. This silicon in the metal bath is a better deoxidizer than ferrosilicon which must be mechanically mixed with the metal bath. Manganese silicate in the slag is reduced to a minimum in the acid electric process.

The sulphur content during the process varies considerably but at the end of the charge is as low as the original sulphur content of the charge. In the oxidation period considerable of the sulphur reacts as follows: $FeS + 2FeO = 3Fe + SO_2$, the SO_2 escaping as in the puddling furnace. Some sulphur is added during the introduction of metallic constituents and coke.

In the basic process the iron sulphide is broken up as follows: $3FeS + 2CaO = 3Fe + 3CaS + 2CO$. Phosphorus in the basic furnace is carried into the slag as calcium phosphate, which is not possible in the acid furnace.

Special care is necessary for conducting an acid slagging process, and on account of the difficulty of melting silica a certain basicity of the slag must be maintained. During the early slagging the oxygen in the base to that in the acid should be 1:2. Later in the deoxidizing slag the ratio may be 1:4, but such a highly acid slag is very often undesirable on account of the high temperature required. The basicity may be raised by lime or magnesia. The lime content should be about 15 per cent as a 20 per cent lime slag attacks the lining. Magnesia is usually between 2 and 5 per cent in a good slag. Ferromanganese also raises the basicity of the slag, but if the MnO in the slag is too high (more than 15 per cent) it can be reduced by coke. The MnO content in an acid slag is usually ten times that in a basic. The acidity of an acid slag is 55-60 per cent SiO_2 for good melting and the oxygen in the base to that in the acid should be 1:3.

Good steel can be made in the acid electric furnace without special precautions, but the process is not easy and a good metallurgical knowledge is requisite. The following points are noted in comparing the acid with the basic electric steel process. For the acid process:

1. Less current demanded because of shorter melting period. The desulphurizing and oxydation practically occur together, and no dephosphorizing takes place.

2. Saving in material for deoxidation. All silicon coming from slag and lining.

3. Lower lining, maintenance and repair costs.

4. Lower cost for slag.

The acid electric furnace is applicable, when a material low in S and P is available, and the process produces a good middle quality steel. However, on account of the powerful reaction of the lining it is only available in certain cases.

Buying and Selling of Ores and Metals

The Buying and Selling of Ores and Metallurgical Products is the title of Technical Paper 83, just issued by the Bureau of Mines. Charles H. Fulton, the author, says: The buying and selling of ores and metallurgical products is a great and highly important business in the United States, and one that concerns not only the miner and the metallurgist but the industrial world in general. In this paper the attempt is made to outline clearly its underlying principles, the subject matter being based on personal experience and investigation. The author has endeavored to present the material impartially, and for that

reason many of the statements and figures regarding metallurgical practice should be taken as illustrative rather than as applying exactly to average operating conditions.

In estimating the value of an ore or an intermediate metallurgical product (other than a refined metal) the basis used is the price of the refined metal at some principal market center, such as New York, at the time the valuation is made. The average price of all copper for 1913 was 15.5 per pound, and for electrolytic copper 15.269 cents per pound. The prices for other metals for the year 1914 were as follows:

Lead, 3.862 cents per pound; spelter, 5.213 cents per pound; silver, 54.811 cents per troy ounce. Gold has the standard value, established by law, of $20.67 per troy ounce.

If the metal contents, in pounds for the base metals and in troy ounces for the precious metals, per avoirdupois ton be multiplied by the prevailing price of the refined metals, the sum of the products will be the gross value of the ore.

There is, however, a wide difference between the gross and the net value of a ton of ore. From the gross value must be deducted, first, the total cost of mining the ore, and then the total cost or charge for treatment, which includes some or all of the following items: Freight to treatment plant, milling or smelting charge, charge to compensate for losses of metal in treatment, charge for penalties imposed on undesirable constituents in the ore, charge for freight to refining center, charge for refining the metal, charge to cover the selling costs of the refined metal. Which of these charges are imposed and what the amount of each charge depends on the ore, the method of treatment, and the number of firms that handle the ore and metals in the process from ore to refined metal.

The types of companies that handle ores and metallurgical products may be classified as follows:

1. Mining and smelting companies or mining and milling companies, which control all the operations from the mining of the ore to the production and selling of the finished metal.

2. Mining companies, which mine and sell ore on certain schedules to smelting or milling companies.

3. Custom smelters or mills which purchase ores and also operate refineries and produce refined metals or sell intermediate metallurgical products to refineries.

Concerns of type 3 may control mines that furnish a part of their ore supply.

4. Refining companies, which purchase metallurgical products, such as matte, and crude metals, and some ores, and produce refined metals.

5. Selling agencies, which place the refined metals on the market.

It is apparent that an ore or the products derived from it may go through many hands before the finished metal reaches the market, and that metallurgical business may be complex. In this report the essentials of the commercial side of metallurgical work are discussed in some detail.

Morgan Producer Gas Machine and Dyblie Reversing Valves is the title of a catalog recently issued by the Morgan Construction Company of Worcester, Mass. This producer was described in this journal, June, 1915. The Dyblie reversing valves are described and numerous illustrations given of their operation in the catalog. A table is given showing the sizes of reversing valves for open-hearth furnaces. The frontispiece of the catalog is a striking etching of The Edgar Thomson Steel Works by the well-known artist, Mr. Joseph Pennell.

Recent Chemical and Metallurgical Patents

Iron and Steel

Titanium Alloys.—Alloys higher in titanium content than usual are patented by Dr. HANS GOLDSCHMIDT and Dr. OTTO WEIL of Germany and assigned to the Goldschmidt Thermit Co. The purpose of these alloys is to provide a means of adding a higher percentage of titanium to iron and steel baths, overcoming the objections previously maintained. The alloys consist of 15-35 per cent titanium, 1.5-3.5 per cent aluminium, and the balance iron. The aluminium lowers the melting point of the titanium and the alloying qualification is increased and the alloys are free from carbon. The alloy containing 24 per cent titanium and 3 per cent aluminium has been found very useful. (1,136,670, Apr. 20, 1915.)

Electrolytic Processes

Hydrogen Peroxides.—Apparatus for producing hydrogen peroxide is patented by Dr. WALTER WEBER and assigned to Henkel & Co., of Düsseldorf, Germany. It is an improvement over previous apparatus patented Sept. 30, 1913 (1,074,549). The previous apparatus did not permit of a higher concentration than 3 per cent and it was impossible to cool the anodes. The improved apparatus overcomes these disadvantages. Fig. 1 shows the essential features. A is a tube of suitable metal coated on the inside with a thin layer of copper amalgam or silver amalgam cathode. It is closed at both ends by screw caps B-B′, a rod shaped anode C is covered by a tubular diaphragm K. The electrolyte, sulphuric acid, is introduced through D into the tube A, and leaves through outlet E. Oxygen under 100 atmospheres pressure is passed in through F, and rises in the liquid. After electrolyzing with a current density of 5 amperes per sq. cm. at 2 volts, the peroxide solution and oxygen passes through G to another cell of the same type, and so on until the desired concentration is reached. (1,144,271, June 22, 1915,and 1,138,519, and 1,138,520, May 4, 1915.)

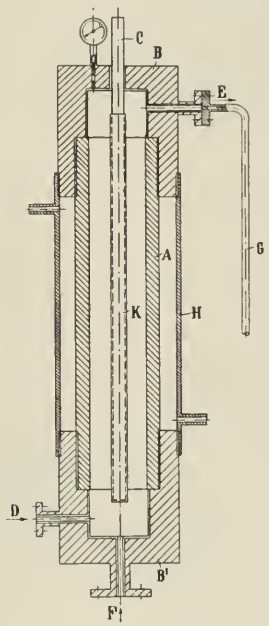


FIG. 1—HYDROGEN PEROXIDE CELL

Potassium Chlorate.—A process of making potassium chlorate by electrolysis is patented by WALTER LAIB of Rittman, Ohio, and assigned to The Ohio Salt Co. In this process a nearly saturated solution of potassium chloride (with a small quantity of chromate) is electrolyzed at a temperature of 35 deg. C. in a cell with carbon or graphite anodes and iron cathodes. This solution is then conducted to a second cell where it is heated by the current up to 70 deg. C. using a platinum anode and iron cathode. In this cell the concentration of chlorate is materially increased and any hypochlorite is converted into chlorate. The solution is then led to a crystallizing vat. The advantages claimed for the process are a saving in cost of anodes over the use of platinum anodes alone and the elimination of hypochlorites. (1,143,586, June 15, 1915.)

Manganese Peroxide Anodes.—A patent issued to Mr. PERCY C. C. ISHERWOOD of England, discloses a process for manufacturing anodes from manganese dioxide ore after treatment for the removal of such

impurities as iron, nickel, or cobalt. The ore is first ground into a finely divided condition, leached with sulphuric or nitric acid, then mixed to a paste with a quantity of manganese nitrate solution and heated. This drives off the oxides of nitrogen and the mass becomes agglomerated. Repeated treatment reduces the porosity of the product. These manganese peroxide anodes are used in copper, zinc or nickel salt solutions as insoluble anodes, and it is claimed that no impurities pass into the electrolyte. (1,143,828, June 22, 1915.)

Fixation of Atmospheric Nitrogen

Oxides of Nitrogen from Air.—A novel apparatus for utilizing the heat of the arc in making oxides of nitrogen from air is disclosed in a patent of Mr. Francis I. du Pont of Wilmington, Del. In the latest form, the apparatus consists of what might be termed a six-cylinder engine, in which air is drawn in through a valve, compressed and then heated by an arc. This causes the air to expand and forces the piston down or up as it may be; at the same time oxides of nitrogen are formed which are discharged together with the expanded air through a discharge valve. Several automatic adjustments are necessary, viz.: valve action, and the top electrode in the cylinder must be made to move down and touch the bottom electrode just at the beginning of expansion. As the top electrode is moved up, an arc is formed and this arc continues for two-thirds of the stroke of the moving electrode or one-third of a revolution of the crank shaft. The six-cylinder arrangement thus permits of a continuous consumption of current in that each cylinder uses the current for one-third of every other revolution. The cylinder is made in the form of a tube of insulating material; glass or silica, to prevent arcing on the sides of same, thus insuring that the air will be heated to the desired temperature. At the temperature of the arc the nitrogen oxide is formed and the cooling of the air due to expansion prevents to a large extent the redecomposition of the oxides of nitrogen formed. A good working current is given as 2 to 10 amperes at 3500 to 5000 volts. The oxides with the air are discharged into a conduit which leads to the apparatus in which they are to be used. The novel characteristic features of the invention are summed up as follows: "In the first place the electric arc is maintained during expansions, whereby heating, expansion and conversion of the heat into mechanical energy proceed simultaneously, whereby all the heat (except that which is carried off by the gases when expanded to atmospheric pressure and that which, due to the imperfection of mechanical devices, is unavoidably lost) is converted into mechanical energy. In other words, drawing out the arc during expansion, continually generates new heat, which is simultaneously converted into mechanical energy, and after the arc breaks and the generation of heat ceases, the gases continue to expand and convert heat into mechanical energy." (1,147,150, July 20, 1915.)

Carbonitrides.—A process for manufacturing carbonitrides is patented by Mr. Samuel Peacock of Chicago and assigned to the du Pont de Nemours Powder Co. The essential feature of this patent is the fixation of nitrogen by a metallic oxide and carbon, forming a compound which approximates the formula $Ca_3N_2C_3N_4$ in the case of calcium, and similar formulas in the case of other oxides such as silicon or aluminium. The manner of carrying out this operation is shown in Fig. 2 in which 1 represents a feeder for the charge which goes into the conically shaped revolving furnace. It consists of finely divided dry calcium oxide and finely divided dry coke or charcoal, in the ratio of 56 parts by weight of the former to 24 parts of the latter. An excess of carbon sometimes as high as 25 or 30 per cent is used, since it prevents the formation of calcium nitrides. Five and 6 are resistors for heating to 1500 deg. C. the charge which is gradually worked toward the discharge end by the revolving of the furnace. Twenty-four is a suction pump to withdraw air and gases formed in the reaction. The air is removed from the furnace before starting the operations and nitrogen is introduced in sufficient quantity. The resulting product is calcium carbonitride $Ca_3C_3N_6$. In boiling water or acids it is decomposed into ammonia and carbonates or into ammonium and metal salts of the acid used. (1,137,524, Apr. 27, 1915.)

Electric Furnaces

Calcium Carbide.—Improvements in the manufacture of calcium carbide are described in a patent of Mr. Frederick M. Becket of Niagara Falls, assigned

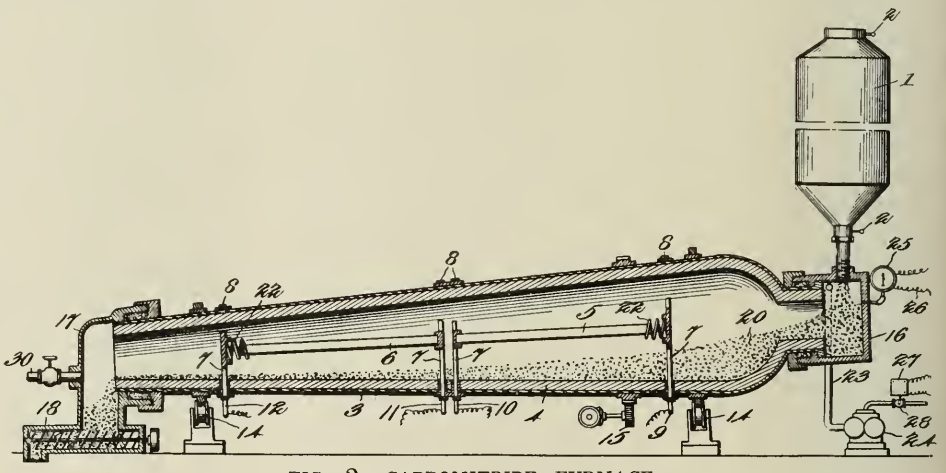


FIG. 2—CARBONITRIDE FURNACE

to the Union Carbide Co. In this process the lime and coal are agglomerated in a by-product coke oven by a coking operation. This is to take the place of briquetting or molding operations and is claimed to be much more economical. In briquetting processes the lime is usually mixed with coke, charcoal or anthracite together with a suitable binder usually a hydrocarbon or carbohydrate. The briquets are formed under high pressure, and baked, if necessary, previous to smelting in the electric furnace.

In the present process calcined limestone is mixed directly with a definite amount of bituminous coal rich in volatile matter. This mixture is then subjected to a coking operation in a by-product coke oven. Grades of coal containing 30 to 36 per cent of volatile hydrocarbons have been used successfully. A coal from the Youghiogheny district in Pennsylvania having the following analysis:

Volatile matter	35.84 per cent
Fixed carbon	53.77 per cent
Ash	10.39 per cent
Total	100.00 per cent
Moisture as received	1.60 per cent

was mixed with freshly burned lime in the propor-

tion of 110 parts of coal to 100 parts of lime, and the mixture was coked in by-product coke ovens of the regular type, the gas, tar, and ammonia being collected as in the usual coking process. The evolved gas was burned for the coking and proved to be sufficient for this purpose. After coking, the resulting mass is crushed to lumps, which may be about the size of the fist, and these lumps then conveyed hot, to the electric furnace. These aggregates are mechanically strong and will endure considerable weathering.

It is necessary to adjust the proportions of lime and coal so that the carbon remaining after the coking operation is practically that required for the reaction.

$$CaO + 3C = CaC_2 + CO,$$

which requires a proportion of fixed carbon equal to about 64 per cent of the lime used. It is this high proportion of fixed carbon required which renders it practicable to supply with the fixed carbon in the coal, a sufficient quantity of bituminous matter to form the strong aggregates. The resulting mixture has been found to have a higher resistance than the ordinary mixtures of lump lime and lump coke, and gives higher yields with less wear on the electrodes. (1,137,567, April 27, 1915.)

A New Multiple-Type Recording Instrument for Pyrometers

The instrument shown in the adjoining illustration has been put upon the American market by Mr. Charles Engelhard, 30 Church Street, New York, in connection with his Heraeus Le Chatelier pyrometer. It is manufactured by Messrs. Siemens & Halske, A. G., Berlin, and conforms in every respect to the high grade instruments for which they are recognized.

The moving system is similar to other types of their instruments, having a double pivoted movement of the D'Arsonval type. The weight of the moving system is extremely small, making it absolutely dead-beat. The ratio between the resistance of the moving coil and the series resistance is so very small that the temperature coefficient is far below that of even a low-resistance instrument. The total resistance of the instrument ranges between 300 and 400 ohms.

Besides being provided with a recording movement, it has also a direct indicating scale, and annunciator, showing the thermo-couple connected at any particular time so that observations may be taken from the instrument as readily as from a direct indicator. The record is formed on a maximum of six thermo-couples, all upon the same chart which is of the continuous roll type, and each record distinguished from every other by being printed in a different symbol. This makes it impossible to confuse the individual records, even though they intermingle or cross at very small angles, and makes it possible to allow the full width of the chart for each record.

But a single galvanometer is employed, the six records being made possible by inserting in the circuit an automatic, mercury contact, switch. This switch is enclosed in the case of the instrument, and forms a part thereof.

The change from one symbol to the next, in accordance with the rotation of the switch, is accomplished by using a roller, situated beneath the chart with six edges, each edge engraved with a different symbol. Over this roller and beneath the chart, slowly moves an inked ribbon. The galvanometer needle, which has a flat surface on its underside, is intermittently depressed every twenty seconds, pressing against the chart, which in turn is pressed against the inked ribbon and engraved edge beneath, so that the symbol on the edge of the roller is printed on the reverse side of the semitransparent chart.

Besides accomplishing absolute distinction between individual records, this method allows the galvanometer needle to swing entirely free between each depression, eliminating all error due to friction. The method further eliminates the necessity of renewing inks or other recording medium.

MULTIPLE RECORDER FOR PYROMETERS

Five hours of record can be observed at all times, as the chart passes down over the face of the instrument. It is then automatically rewound upon a spool in its original form.

The endeavor has been to make this instrument foolproof and thoroughly automatic in every sense. It takes the place of six individual recorders, is compact, extremely accurate, has the advantage of high resistance, and is not affected by vibrations.

Determination of Critical Points in Iron, Steel and Alloys

The Scientific Materials Co. of Pittsburgh, has developed and placed on the market a complete apparatus for the accurate determination of critical points in iron, steel and non-ferrous alloys. A view of the complete outfit is shown in Fig. 1 (p. 644).

The importance to the industries of accurate data on transformation points cannot be underestimated, as the whole field of heat treatment depends upon these phenomena. The Scimatco method is an adaptation of the most sensitive and accurate method which has been devised for detecting and measuring small thermal changes in solid bodies. It is based upon automatic comparison of the temperature, during heating and cooling, of the metal test specimen with that of another "neutral" body, which has no transformation points of its own (at least not within the temperature ranges studied). Both are heated and cooled together in one vertical heating chamber under absolutely uniform conditions.

A convenient manner of introducing the thermocouples into the test piece and neutral body which insures the rapid action of the heat and eliminates scale formation (oxidation) is provided. The critical points are read directly on a specially designed duplex instrument and a special chronograph is provided from the records of which all kinds of curves may be plotted.

In Fig. 2 the general arrangement of heating chamber and bodies is shown, W is a coil of resistance wire underneath a metallic plate T, which serves as a tem-

perature equalizer. The test specimen with holes drilled for thermo-elements is shown at S and the neutral body at N. The holes T_1 and T_3 should be at the same distance from the furnace walls.

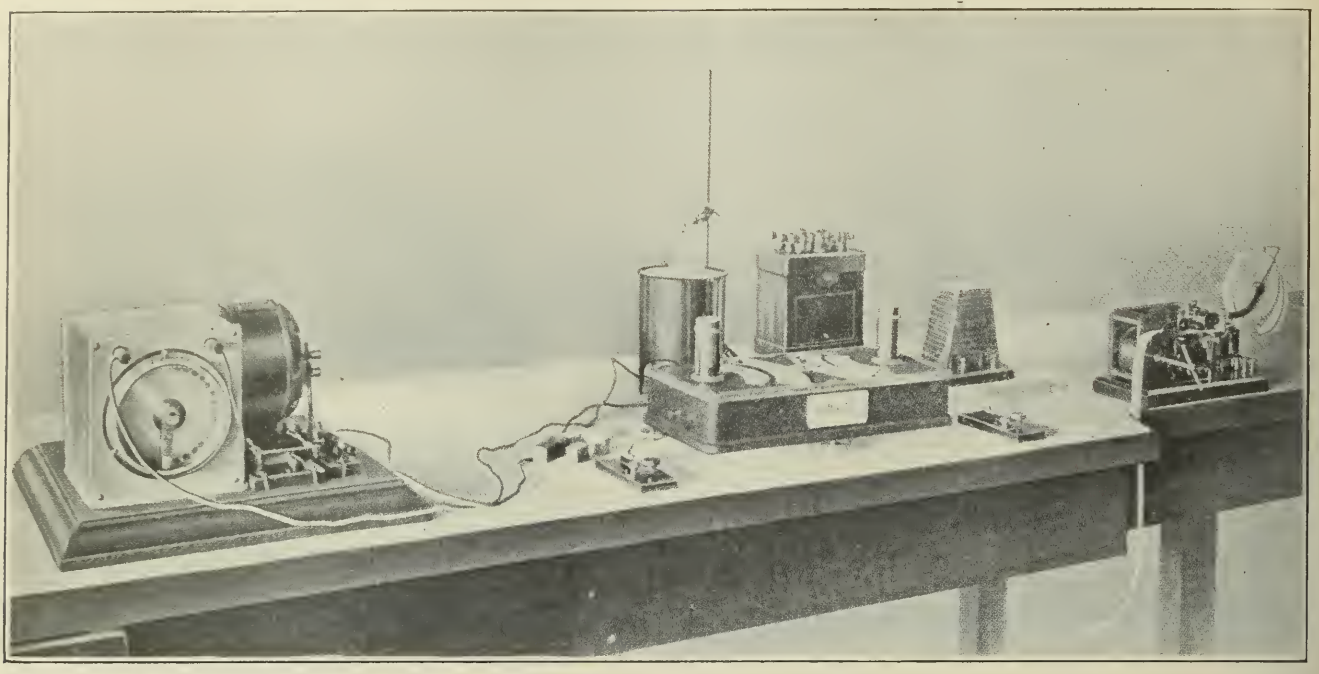


FIG. 1—COMPLETE SCIMATCO OUTFIT FOR THE ACCURATE AND CONVENIENT DETERMINATION OF TRANSFORMATION POINTS

Two platinum, platinum-rhodium thermo-couples are used, one to indicate the actual temperature of S and the other to indicate any difference in temperature between S and M. These thermo-elements are mounted in special insulating tubes and placed in the drilled holes, as shown in Fig. 3. Scale formation is prevented in this manner.

The duplex galvanometer has one scale for indicating the temperature of the test piece and another scale for indicating differences in temperature of the neutral and test pieces. In case it is desired to take the factor of time into account the special three-pen chronograph and automatic contact clock are provided. These record mens and speed of heating and cooling and duration of critical ranges. From these records any kind of curve may be plotted.

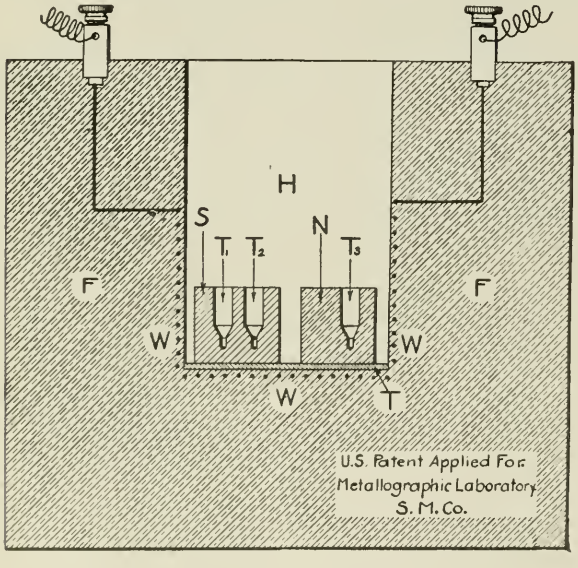


FIG. 2—VIEW OF VERTICAL HEATING CHAMBER WITH TEMPERATURE EQUALIZER AND BODIES

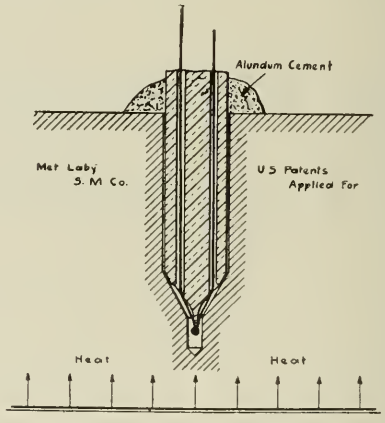


FIG. 3—POSITION OF THERMO-JOINT AND MOUNTING IN THE STEEL BODY

An automatic rheostat for even heating and cooling completes the apparatus, all of which may be seen in Fig. 1.

A metallic alloy suitable for use as packing rings on locomotives using superheated steam is the subject of a patent by G. C. Holder, of Altoona, Pa. The alloy consists of nickel, 3 to 9 per cent; copper, 20 to 30 per cent and lead, 61 to 77 per cent. The hardness of the alloy can be changed by varying the copper content. The composition is comparatively strong and elastic.

The Bausch and Lomb Optical Co. of Rochester, N. Y., has issued a catalog of Optical Instruments for Inspection and Testing of Materials. This catalog describes microscopes for the examination of ores, metals, rocks, concrete, wood, leather, fabrics, paints, varnishes, oils, dyes, inks, drugs, chemicals and foodstuffs. Metallographical apparatus is also included.

Titan Bronze

Through the picturesque Bald Eagle Valley, in Centre County, Pa., runs the Spring Creek. On its banks, in a spot perhaps two miles from the county seat, Bellefonte, there was established, in 1797, the Milesburg Iron Works. Hard by lies the little village of Milesburg, laid out and developed simultaneously with the iron works.

FIG. 1—ROLLING MILL DEPARTMENT OF TITAN METAL CO., BELLEFONTE, PA.

In common they derived their name from their founder, Col. Samuel Miles. During the half century following, the business changed hands six times until in 1849 J. M. McCoy, J. H. Linn and Moses Thompson joined a former part owner, James Irving, in forming the firm of Irving, McCoy & Co. In 1860 Irving withdrew and from that day to this the business has been operated under the name of McCoy, Linn & Co. It is now part of the McCoy estates and is actively managed by Mr. John McCoy.

When the charcoal iron industry was at its height there were operated at Milesburg a blast furnace, charcoal forge, puddling mill, rolling mill and wire mill. Except for the blast furnace the plant lay idle for considerably over a decade until April, 1915. But despite reports to the effect that no iron is now produced in Centre County, McCoy, Linn & Co. have never ceased to operate what is now one of the very few remaining cold-blast, charcoal iron furnaces now active in this section of the State.

After lying thus idle during these many years, title to part of the McCoy property was taken over by the Titan Metal Co. of Bellefonte, Pa., in April of this year. This company is incorporated under the laws of the State of Pennsylvania and is being financed by the business men of Bellefonte. Its officers are C. E. Wagner, president; John Walker, vice-president; W. P. Sieg, secretary and general manager, and F. E. Naginey, treasurer.

The chief product of this company—titan bronze—bids fair to revolutionize certain lines of industry lying within its field.

Titan bronze has been perfected after a number of years of research and experimental work on an elaborate scale. It has high tensile strength and is forgeable. For drop forging it is superior to any similar metal on the market. One of its peculiarly valuable properties is that it can easily be worked hot to a finished form with high tensile strength, and in press work without injuring the dies.

It is supplied in bars, cold rolled and cold drawn, having a tensile strength of 110,000 lb.; in hot-rolled bars and in hot or cold-rolled sheets for hot or cold forming; in castings and recasting ingots. In the very near future the metal world is promised further valuable developments in the form of bronze-covered sheets and bronze wire.

Titan bronze, because of its extremely plastic nature at working temperature, is especially well adapted for

FIG. 2—DROP FORGING OF TITAN BRONZE. LARGE DIAMETER ROD USED TO SHOW SPREAD OF METAL IN FLASH

drop forgings, gears and pinions, hot press work, roller bearings, balls, valve seats, pump rods, etc.

An ordinary hot-rolled bar of titan bronze will show the following properties: tensile strength, 80,000 lb.; elastic limit, 45,000 lb.; elongation, 25 per cent; reduction of area, 45 per cent.

A tremendous amount of work has been done since the new company took title to the old plant. The substance of a modern fire-proof structure, unsurpassed by

any works of the size in the country, has risen from the skeleton of the old plant. The rolling mill is equipped to handle non-ferrous metals of every description and an inspection of the foundry, stamping mill, casting, drop forge and machine shops affords conclusive evidence that the new concern is well equipped to handle its product in every conceivable form.

Hydraulic Hardness Testing Machine

A new hardness testing machine has been developed and placed on the market by Messrs. Eimer and Amend of New York. This machine works on the well-known Brinell principle of making indentations in the metal and measuring the width of same. It is represented in Fig. 1.

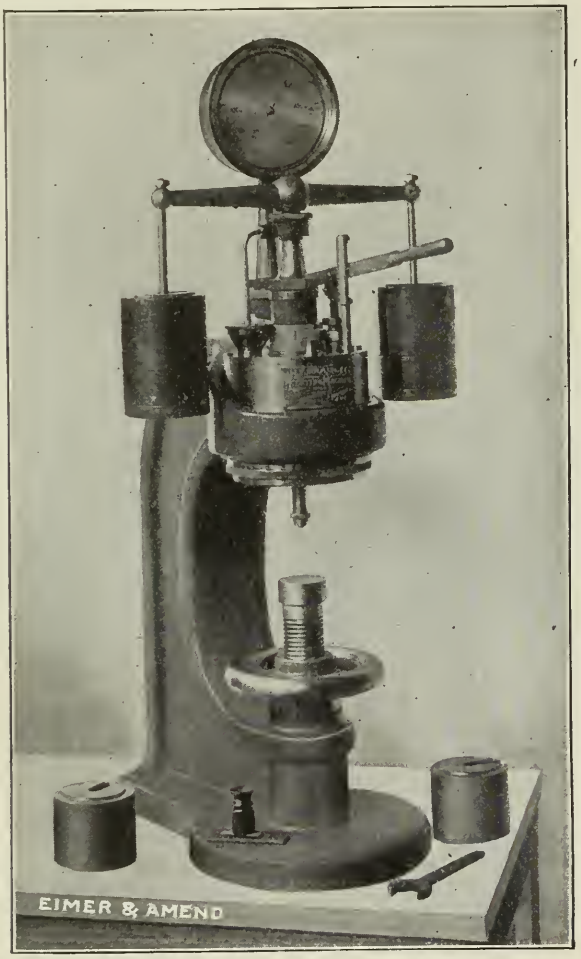


FIG. 1—HYDRAULIC TESTING MACHINE

In order to conform to the demands of most testing laboratories the heavy goose-neck style has been adopted. Controlling weights are provided if desired. By their use wrong readings are entirely excluded; if the manometer should get out of order this device will show the error.

The main parts of the machine are: the hydraulic press, the hand pump, and the pressure gauge with the attachment for the controlling weights. The machine is filled with oil and a pressure of 3000 kilograms (6614 lbs.) is produced by about ten strokes of the hand pump.

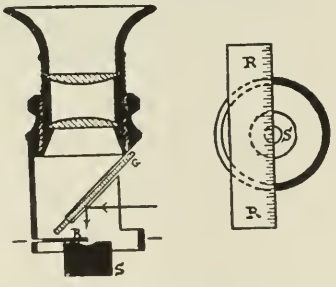


FIG. 2—MICROSCOPE

A special microscope shown in Fig. 2 is provided to read the width of impressions. The reflector G furnishes a strong illumination for the test piece S and with the aid of the small steel rule R fitted in the bottom of the cylinder, the exact diameter can be read to 1/10 of a millimeter.

Personal

Dr. **H. K. Benson** of the University of Washington, Seattle, Wash., is making a trip East and will attend the National Exhibition of Chemical Industries in New York City.

Mr. **William C. Coffin** has severed his connection with the Jones & Laughlin Steel Company, to become vice-president of the Knox Pressed & Welded Steel Company of Pittsburgh, Pa. Mr. Coffin was vice-president of the Riter-Conley Manufacturing Company from 1898 to 1908, and since then has been structural engineer of the Jones & Laughlin Steel Company. Mr. Coffin's new office will also include the duties of general sales manager. With the acquisition of Mr. Coffin the officers of the Knox Pressed & Welded Steel Company now are Luther L. Knox, president; William C. Coffin, vice-president and sales manager; Irvin F. Lehman, secretary and treasurer. The approaching completion of the new Knox plant was the deciding factor that brought Mr. Coffin to this company. The new plant of the Knox Pressed & Welded Steel Company will be given over to riveted and welded steel plate work, while the company's present plant at Farrell, Pa., will be continued in the manufacture of the Knox patented water-cooled devices for open-hearth and heating furnaces.

Dr. **C. H. Herty** of the University of North Carolina, president of the American Chemical Society, was recently in New York and did very effective good work for the National Exhibition of Chemical Industries, of whose advisory committee he is a member.

Mr. **Lewis A. Riley, 2d.**, mechanical and gas engineer, has taken over the agency in the United States and Canada for the Lymn system of by-product gas producers, which has made such rapid strides in Europe during the past five years. The Lymn system is an improvement and development of the Mond system of by-product gas production; it was described in some detail in our July issue, page 456. Mr. Riley has taken offices in the Vanderbilt Concourse Building, 52 Vanderbilt Avenue, New York City.

Book Review

The Mining Manual and Mining Year Book for 1915. By **Walter R. Skinner.** 968 pages. Price 15s. net (Post free in U. S. 17s.). London: Walter R. Skinner.

In this edition of this large annual devoted to data on the mining companies of the world, companies are arranged alphabetically instead of being divided into sections as heretofore. The reference data are very complete and contain besides the statements as to capital, data of registration, etc., an analysis of the last balance sheet, dividends from the start, details of ore reserves, borehole results and description and capacity of treatment plant. The volume contains particulars of 2420 companies and also an index of 2580 additional companies whose field of action has either ceased or is not of public interest. Alphabetical lists of mining directors, secretaries, engineers and mine managers are included as usual and a dictionary of mining terms is added. These features make a very complete work and it should prove of value to any one requiring up-to-date information on mining companies.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIII NEW YORK, OCTOBER 1, 1915 No. 11

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH OF EACH MONTH BY THE

McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DeMOTT, Treasurer

239 West 39th St., New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Col.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for October 1, 1915

EDITORIAL:

What the Chemical Industry has a Right to Expect from the American Nation 647
Scarcity of Steel 647
Expositions and Exhibits 648
A New Agricultural Use for Sulphuric Acid 648
By-Product Coking 649

READERS' VIEWS AND COMMENTS:

The Electric Furnace in the Foundry. By N. Petinot.... 650
Britannia Linings for Hardinge Mills. By George E. Collins 650
Niagara Falls Section of the American Electrochemical Society 651
The Western Metallurgical Field 651
The Iron and Steel Market 653
The New Director of the Bureau of Mines 654
San Francisco Meeting of American Electrochemical Society.. 654
San Francisco Meeting of American Institute of Mining Engineers 654
Metallurgy at International Engineering Congress (with full reports of the symposia on iron and steel and on copper). 655
The Aniline Dye Situation. By I. F. Stone 663
Slime Agitation and Solution Replacement Methods at the West End Mill, Tonopah, Nev. By J. A. Carpenter..... 671
The Necessity of Tariff Reform for the American Chemical Industries 676
Applied Chemistry. By Leo H. Baekeland..... 677
Notes on Reverberatory Smelting Practice of Nevada Consolidated Copper Company. (Editorial Correspondence)..... 681
The Estimation of Aromatic Hydrocarbons in Cracked Petroleum. By W. F. Rittman, T. J. Twomey and G. Egloff.... 682
Snythetic Phenol and Picric Acid. By A. H. Ney..... 686
First National Exposition of Chemical Industries..... 690
RECENT CHEMICAL AND METALLURGICAL PATENTS..... 700
NOTES 701
Rennerfelt Electric Furnace 702
Protecting Polyphase Motors Against Phase Failure and Reversal 703
Water Distilling Apparatus 704
Gigantic Conveyor Belts 704

What the Chemical Industry Has a Right to Expect from the American Nation

"The only true basis on which the *independence* of our country can rest, are agriculture and manufacture. To the promotion of these nothing tends to a higher degree than *chemistry*." These words were placed as a motto above the exhibit in the American Electrochemical Society booth in the First National Exposition of Chemical Industries in New York City last week. They were taken from Thomas P. Smith's oration before the Chemical Society of Philadelphia on April 11, 1789. They are as fresh and true to-day as they were 117 years ago. But the American nation as a whole is only now beginning to grasp the idea of the intimate relationship between its very independence and chemistry.

The European war brought about suddenly this recognition. The general public then realized for the first time how interwoven the work of the chemist is with the whole industrial life of the country, and because the existing chemical industries could not supply all the country's needs, those who were left in want (because they had never shown any particular appreciation of American chemical industries) combined with American newspapers in an abuse of the American chemist that was as unfair as it was stupid. But the American chemist quietly went his way and did things, many things. Part of this activity will stop when the war stops, as it has to do with war materials. But by far the most of the present activity in the chemical industries will be lasting for the benefit of the whole country, if the American nation is willing that it be so. What is it that the chemical industry has a right to expect from the American nation? Nothing more nor less than a fair attitude of mind of the American nation toward American chemistry: a fair appreciation of its accomplishments and aims, a fair recognition of the fact that chemical brains need capital for realization of their ideas and that capital needs fair protection, not forever, but for a sufficient time to permit the chemical manufacturers to adjust themselves to the changed conditions and new requirements. Whatever was said in the meetings held in connection with the Chemical Exposition by Dr. Baekeland, Mr. Gross, Dr. Herty, Mr. Stone, and others on needed reforms, may be summed up in the single demand for plain fairness. And this augurs well. For the American people may be misled for a while, but ultimately they will always be found fair and right.

A Scarcity of Steel

It is being said in the steel trade that there is a scarcity of steel. It requires some knowledge of steel trade parlance to appreciate the significance of the

statement. The meaning is not that the supply has been curtailed so as to result in a scarcity, nor is it yet that the demand for steel products has outrun the supply. The precise meaning the trade attaches to the expression is that the steel ingot making capacity has been found to be far short of the supply of raw materials for steel making on the one hand, and far short of the rolling and other steel finishing capacity on the other hand.

The steel industry as a whole is busy, but the steel-making departments are the busiest. The steel interests still have a few idle blast furnaces that could be blown in, and there are many merchant furnaces idle. There is an abundance of ore, and coke is so plentiful that Connellsville furnace coke for spot shipment has been selling at one-half the price it commanded the last time the market price of steel billets mounted to the present level. The majority of the steel-finishing departments are not fully employed, and some can hardly be regarded as moderately well employed. Exception must be made of bar and rod mills and of wire-drawing departments, which are under pressure.

The present condition, of there being a scarcity of raw steel, relative to supplies for the steel-making departments, and capacity for converting ingots into merchantable material, is due in part to the abnormal character of a part of the present demand for steel. In the first place, a large tonnage of steel is being produced under stringent specifications as to cropping, whereby the tonnage of steel rolled, in proportion to the tonnage of ingots produced, is reduced. In the second place, there is a heavy demand for forging billets, to be used in the manufacture of large shells, and thus steel is taken that ordinarily would be rolled beyond the billet form.

It is possible that the output of steel ingots from the steel-making facilities in employment is less than it would be were demand of its usual character. The necessity of making much steel of special grade may prolong the time in the case of open-hearth heats and may possibly reduce the tonnage per heat. Not enough is known to justify the making of a generalization.

Expositions and Exhibits

There is nothing more effective to drive home a lesson than a direct appeal to the senses. What no amount of lecturing can accomplish is often easily impressed on the mind through the eye which sees, admires and understands, and it is this combination of the perception of beauty with instruction which makes the success of expositions.

No one who has seen the San Francisco Exposition can have escaped the sorrowful reflection that so much beauty shall soon be gone forever. Yet expositions are essentially ephemeral. They come and go like thieves in the night. A permanent exposition seems an impossibility; it surely is if it is to be self-supporting. While the success of an exposition cannot and should not be measured by dollars and cents, yet the financial success or lack of success is at least one pretty safe indication whether or not an exposition has fulfilled its higher missionary function. To be a financial success an exposition must be limited in time; it should be long enough to be seen by all who should be interested, and short enough to reduce the operating expenses to a minimum. This period of time must be correctly judged and will vary from case to case. To limit the highly successful Chemical Exposition in New York City last week to six days, seems to have been exactly right, although we have heard more than once an expression of regret that the show would be over so soon. And what is true for expositions in limited fields is just as true for "world's fairs."

But what is true for expositions is not necessarily true for the exhibits. An exhibit can be made permanent under normal conditions and should be made permanent, if this is possible. It is true, a fine exhibit can be set up quickly by the right man; Dr. Doremus showed this in arranging single-handed in a few days the really pretty little historical and technical exhibit for the American Electrochemical Society booth at last week's chemical exposition; it is a pity that this exhibit could not be made permanent because it had been obtained by loan from many sources. But most other exhibits can be made up with a view to permanency. It is unthinkable that the wonderfully instructive exhibit of the United States Steel Corporation at San Francisco should not be preserved permanently and used over and over again at different places as an almost inexhaustible source of instruction. What magnificent results can be obtained if an exhibit is built up with a view to permanency and gradually perfected, is shown by the exhibit in the Canadian Building in San Francisco which has elicited and will always elicit so much truly deserved admiration. This is a lesson which the average exhibitor at expositions has still to learn. The fine exhibit of the different government bureaus at the Chemical Exposition had been specially prepared for this occasion, but it could and should be kept together as a nucleus for future extension.

A New Agricultural Use for Sulphuric Acid

Is agriculture about to derive a new benefit from the application of sulphuric acid to alkali soils? And can the smelter foresee a partial outlet for a product, one of the constituents of which has caused him vexation and expense at the hands of the prospective beneficiary? And is chemical research on the eve of demonstrating another instance of the interdependence of widely different industries, through the conversion of a waste product of the one into a substance useful to the other? An affirmative answer to these queries is suggested by the results of two years of investigation by Dr. C. B. Lippman, of the University of California.

At one of the sessions of the recent San Francisco meeting of the American Institute of Mining Engineers, Dr. Lippman explained the nature and results of his investigations, and illustrated by photographs the ap-

parent beneficial results obtained by applications of sulphuric acid to alkali soils. The views showed crops growing on test plots that had received from 2½ to 7½ tons sulphuric acid per acre, the ground being otherwise unfit for agricultural purposes on account of the concentration of alkali salts. One effect of the acid is to cause a shrinkage of the colloids, giving a better opportunity for aeration of the soil and circulation of moisture, and creating more favorable conditions for the activity of nitrifying bacteria.

An important feature of the work from the metallurgical standpoint is the quantity of acid used, running into tons per acre. From the agricultural side there is prospect of rendering useful a vast acreage of ground in the Western States, now lying waste and shunned by the farmer. Here is prospect of co-operation for mutual good between interests that have regarded each other with suspicion and enmity. The smelter may yet prove to be one of the agents for making the desert blossom as the rose.

By-Product Coking

The rapid substitution of the retort for the beehive process of making coke in the iron industry that is occurring at this time may be looked upon as a metallurgical triumph, but it is really a financial achievement. Success from a technical standpoint occurred years ago in the manufacture and use of retort coke as the iron blast furnace fuel, and the building of by-product coking plants at the present time is proceeding chiefly in accordance with the quantity of funds available. In the circumstances the increase year by year in the proportion of by-product coke manufactured is slow rather than rapid. The growth is a function of the earnings of the iron and steel producers rather than of the economies assured by the process. Probably it would be difficult to find an engineer in any industry who would not insist that his employers or prospective clients were particularly slow in investing their capital in improvements promising economy, but the whole history of the iron and steel industry shows how it is continually demanding more and more capital. At the present time the industry is investing more of its funds in by-product coking plants than in any other single item.

The growth in by-product coke production is really slow. Last year was no criterion, as iron production was small and slightly less by-product coke was made than in 1913, while there was concurrently a large decrease in the beehive production, whereby the 11,219,943 net tons of by-product coke made in 1914 comprised 32.5 per cent of the total coke output, while the 12,714,700 tons of by-product coke made in 1913 comprised 27.5 per cent of the year's coke output. One-half as much by-product coke was made in 1909 as in 1913, one-fourth as much in 1905 and one-eighth as much, approximately, in 1902, showing successive doublings in three, four and five years respectively.

Of the total coke produced, as reported by the Geological Survey, which does not take account of gashouse coke, fully 80 per cent is consumed in the manufacture of pig iron, and thus the matter of replacing the beehive oven with the retort oven is chiefly the concern of the blast furnace. In view of the fact that the gas can be profitably employed in the steel works it is at the blast furnaces of the steel works more than at the merchant blast furnaces that by-product ovens are being built. A further differentiation can be made, that the consumers who have beehive ovens have been less disposed to build by-product ovens than those who have had to purchase their coke in the open market. Connellsville coke has frequently sold at very low prices, but it has always advanced to a very high level when there was a heavy demand, often doubling in price. The buyer has therefore paid more than the apparent average price, because he bought more high priced coke than low priced. Of late the building of by-product ovens has proceeded more rapidly than the erection of blast furnaces, a circumstance that has prevented the coke market from experiencing its usual sharp advance at this time when the production of pig iron has become very heavy.

It may be estimated that there are now being built, or definitely projected, by-product ovens having an annual capacity of about 4,000,000 tons, and as it is usually not far from a year from the inception of the enterprise to the actual production of coke the rate of growth in output is at the moment at the rate of not far from 4,000,000 tons annually. The present capacity seems to be somewhat under 15,000,000 tons, while as closely as can be approximated the coke requirements of the existing blast furnaces, if they were required to operate at capacity, would be about halfway between 40,000,000 and 45,000,000 tons. Even with the completion of the present new construction, therefore, the iron industry will not have accomplished one-half its task of arranging to supply itself with by-product instead of beehive coke. The remainder of the operation will be carried out largely as funds become available. The incentive to invest capital in this manner will in general be less in the future than it has been in the past, for the reason that thus far by-product ovens have been built chiefly by interests that had been buying coke, or were building blast furnaces in excess of their present coking facilities. In a short time there will be few blast furnaces using beehive coke except those that produce it themselves, or detached merchant furnaces to which the capital outlay would be somewhat disproportionate to the size of the present investment. It is to be expected, however, that even the furnace interests that have beehive ovens will gradually abandon them in favor of retort ovens located alongside the furnace.

Of course, the principal single stimulus which has caused this rapid development in by-product oven construction is the cutting off by the war of the importations of the coal-tar distillation by-products for which there is such an urgent demand by the chemical and allied industries. Just now it pays very well to invest in by-product coke ovens not for the sake of the coke, but for the sake of the by-products. But this is another story which may be reserved for another time.

Readers' Views and Comments

The Electric Furnace in the Foundry

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I have read with considerable interest the paper entitled "The Electric Furnace in the Foundry," written by Mr. Wm. G. Kranz and to be presented at the San Francisco meeting of the American Institute of Mining Engineers, which appeared in the Sept. 1 issue of Metallurgical & Chemical Engineering. I have forwarded a copy of this discussion to the secretary of the American Institute of Mining Engineers for presentation at the San Francisco meeting (Sept. 16 to 18).

I agree perfectly with Mr. Kranz that steel for castings made in an electric furnace is not because of that fact all necessarily good steel, and also that the qualities which he mentions, such as absence of segregation, elimination of sulphur, great tenacity, etc., can be obtained in an electric furnace if operated under proper metallurgical conditions.

An unusually low content of sulphur in steel for castings is not, of course, an absolute necessity and the range of this element usually obtained in steel made in basic open-hearth furnaces is sufficiently low to meet all physical requirements.

The main factor in making steel for castings regardless of the process is the complete deoxidation of the bath to prevent the formation of segregation and also increase the physical qualities of the steel. Such complete deoxidation is accomplished in basic electric furnaces by holding the metal sufficiently long in the presence of a blanket of carbide of calcium, as in the Heroult or Stassano process or by the addition of 50 per cent ferrosilicon, as in the Girod or induction furnace process. However, if steel is as completely deoxidized in the furnace that when, as pointed out by Mr. Kranz, an addition of aluminium or titanium is made the added metal will not oxidize but will be found in the metallic state in the steel, there can be no doubt that such steel will reoxidize during the tapping of the furnace and also during the teeming from the ladle into the molds.

While Mr. Kranz has undoubtedly through inadvertence failed to mention the fact, it is probably the practice at his plant to add aluminium in the ladle during the tapping of the furnace to completely deoxidize the steel.

If, as I assume, it is therefore a necessity under any circumstances to complete the deoxidation of the steel in the ladle, while appreciating the fact that an electric furnace properly controlled must give a more completely deoxidized product in the furnace than it is possible to obtain in such oxidizing processes as open hearth and converter, I still question its great advantage if it is still necessary to complete the deoxidation in the ladle.

In the schedule below I have reproduced Table No. 1 showing the comparative properties of electric and basic open-hearth steel as printed in Mr. Kranz's paper, and also the results of samples from six heats of basic open-hearth and converter steels of approximately the same chemical composition.

These six analyses are representative of the quality of thoroughly deoxidized steel produced under good foundry practice, and it will be noted that the physical properties compare very satisfactorily with those of the electric steel reported by Mr. Kranz.

Mr. Kranz mentions that "absence of segregation and oxides has been firmly established by a great many investigations in our chemical and physical laboratories," and states as a proof of this fact that when ferrotitanium or aluminium is added to their electric steel either of these metals will be found as much in the steel, indicating that no oxides were present which would cause their oxidation.

Table I.

	Elastic Limit	Ult. Str.	Elong.	Red	C	Mn	Si	S	P	
Electric steel..	36,400	65,300	36%	55%	.24	.52	.25	.019	.010	Referred to by Mr. Kranz
O. H. Basic....	34,800	63,000	29.5	35	.23	.53	.24	.038	.011	
O. H. Basic....	40,900	70,400	35.9	56.3	.24	.55	.30	.020	.020	
O. H. Basic....	36,200	64,200	35.9	61.3	.23	.51	.35	.020	.012	
O. H. Basic....	35,800	68,300	35.9	61.4	.23	.77	.34	.027	.012	
O. H. Basic....	38,700	61,600	35	54.0	.19	.56	.22	.027	.014	Test piece unannealed
Converter Steel	38,000	69,200	32	53.6	.21	.76	.37	.055	.041	
Converter Steel	40,500	71,000	32	52.8	.21	.68	.34	.052	.044	

I am inclined to believe that many metallurgists will be interested to obtain full details in reference to this particular point made by Mr. Kranz. Personally, I have made hundreds of heats of steel in the same type of furnace which he is using. In many of these heats 0.10 per cent titanium was used, and in no case have ever traces of titanium been found in the finished casting.

At other times I have used aluminium in the ladle and occasionally adding it into the stream of steel as it flowed from the ladle into the folds, particularly at the end of the operation, because this addition of aluminium was judged necessary to insure the soundness of the castings. In no case has aluminium been found in the finished casting, but in every case where an examination has been made for it the presence of alumina, the oxide of aluminium, has been established both by chemical and microscopical means.

I am of the opinion that what Mr. Kranz has reported as aluminium in the steels which he has treated with that metal, is in reality alumina, and I believe that more complete information on this particular point will interest metallurgists generally.

N. Petinot.

Titanium Alloy Manufacturing Company,
Niagara Falls, N. Y.

Britannia Linings for Hardinge Mills

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In the interesting article in your August issue by H. C. Parmelee, on the Caribou mill in Boulder County, Colorado, he refers to their experience with Britannia lining for Hardinge mills, which seems to have been wholly unsatisfactory. A later experience with the same material at the Mary Murphy mill suggests that the condemnation at the Caribou mill may have been premature.

Having adopted the use of 2-in. manganoid steel balls instead of pebbles for our 4½-ft. mill, because of the increased capacity thereby obtained, we soon found that the life of the silex linings which we had been using theretofore was unduly reduced by the use of the steel balls.

We planned to try chrome steel lining, but as this would take a long time to make and deliver, we decided to use a Britannia lining in the meantime.

We obtained some of the discarded pieces of rail from the Caribou plant, which on arrival proved to be considerably worn and smooth at the edges, showing that when formerly used the mills had been run for a long time

after the lining had given way. The pieces of rail were, furthermore, encrusted with cement in places, which could not be completely removed by chipping without unwarranted expense. Owing to these conditions, the lining hardly had a fair chance.

The pieces of rail were embedded in a mixture of two parts sand to one part cement, fitted as closely as possible, and left to harden seven days. The work of lining occupied five days, as only one section could be completed at a time.

After being in use, the portion around the manhole gave some trouble at first by becoming loose. To overcome this we drove in worn balls into the interstices between the rails, hastening the process of wedging with balls which would no doubt have taken place naturally sooner or later.

Since that time the mill has been in operation ninety days, during which it has ground approximately 2500 tons of very tough ore, and it looks as if the lining will last from thirty to sixty days yet. Had the rails furnished to us been hardened as Hardinge recommends, the life of the lining would have been still greater.

In our judgment, apart from the loss of time in lining, the Britannia lining answers very well indeed. Its installation would be considerably facilitated by bolting rings around the manhole and at both ends, to which the rails might be wedged tight. If this were done, we believe there would be no difficulty whatever, with ordinary care, in getting the lining to stand. Another improvement would be to use progressively shorter pieces of rail to line the conical ends.

In our opinion, the principal drawback of the Britannia lining is the wasted space, because of which, and of the time required for lining, we do not expect to adopt it for the Hardinge mills at the Mary Murphy.

The difficulty at the Caribou mill, as to the 6-ft. Hardinge, may have been due to the very heavy balls in use there (5 in. in diameter).

Denver, Colo. GEORGE E. COLLINS.

Niagara Falls Section of the American Electrochemical Society

(From Our Special Correspondent)

The organizing meeting of the Niagara Falls Section of the American Electrochemical Society commenced with reasonable promptness at 8 h. 0 m. 30 s. p. m. on Sept. 16. Mr. F. A. J. FitzGerald, whose protests were drowned by cries of "Oh, go ahead, be a sport!" was railroaded into the office of temporary chairman which he filled in a more or less desultory manner throughout the evening.

The minatory tones of the secretary, Mr. A. T. Hinckley, prevented any opposition to his proposal that his own minutes be accepted without reading, and Mr. Acheson Smith reported the minutes of the organizing committee, and asked for comments or criticisms on the proposed by-laws. As everybody likely to protest had been put on the organizing committee, no one, naturally, had any to offer, and Mr. Acheson Smith then reported the following nominations on behalf of the nominating committee: President, F. A. Lidbury; vice-president, L. E. Saunders; secretary, A. T. Hinckley. Someone moved that Hinckley cast one vote for himself and the rest; he blushed and did.

At this point the chairman got so fidgety that it was thought advisable to adjourn the meeting, and, the president and vice-president elect arriving at this junction, a "business session" was thereupon held at the Hotel Imperial, where the executive committee might have been seen at one end of the long table fixing plans for raising the wind—and other things.

The following telegram was sent to President Addicks of the American Electrochemical Society at San Francisco: "The Niagara Falls Section at the conclusion of its organizing meeting sends best wishes to the parent society for as lively and successful a meeting as its own sessions promise to be."

On Tuesday, Oct. 12, the section will get down to business. Operating men, power-plant engineers and, as is hoped, some eminent designers of transformers will, under the seal of the confessional, speak to each other on the subject of "Transformers for Electric Furnace Work" with as much politeness as is consistent with frankness and truth.

The Western Metallurgical Field

State Licenses for Colorado Ore Buyers

In accordance with the provisions of a bill passed by the last Colorado Legislature, effective Nov. 1, all individuals or companies engaged in ore-buying in the State are required to take out a license at a cost of $100 per annum. The bill had its inception with Cripple Creek operators who have long sought some effective means of preventing "high-grading" by alleged assay offices and other places for disposing of stolen ore. By requiring all ore buyers to take out licenses and keep accurate records of their purchases, it is hoped that illicit buying of rich ore will be minimized. Legitimate reduction works already keep careful records of the source of the purchases, and the additional requirement of a $100 license fee is probably cheerfully accepted by them in the interest of the mining industry. As in most cases of such legislation, some individuals buying ores and similar materials in a legitimate way will find the annual fee a burden. Annual losses from the stealing of rich ore in such camps as Cripple Creek run into enormous sums which the present legislation hopes to divert into legitimate channels.

Heavy penalties in the nature of fines and even of prison sentences can be imposed for convictions under the law.

Safety and Efficiency Engineering at Colorado School of Mines

The opening of the Colorado School of Mines for the regular fall session was marked by the dedication of the Joseph A. Holmes chair of Safety and Efficiency Engineering, a new department established in memory of the late director of the Bureau of Mines. Governor Carlson made the dedicatory address and the exercises were attended by members of the State Industrial Commission, which is charged with the administration of workmen's compensation in Colorado. State officials and engineers have evinced a keen interest in the establishment of this new chair through the initiative of Dr. William B. Phillips, president of the school. It stands not only as a fitting memorial to a man who devoted the best years of his life to the promotion of safety and efficiency in the mining and metallurgical industries, but also as an active means for training young engineers in those two paramount features of modern industrial work. No appointment has yet been made to the new professorship, but it is expected that Dr. Phillips will shortly recommend a suitable man for election by the trustees. The necessary equipment will be purchased and the courses of study correlated with those of the other departments. In addition to the work of instruction at Golden, it is expected that subsequent developments will bring the new department into close relations with operators, miners and millmen throughout the State.

New Club House for Employees of Nevada Consolidated Copper Company

The accompanying illustration shows the new club house under construction at McGill, Nev., for the employees of the Nevada Consolidated Copper Company. The building is being erected and furnished by the company, and when completed will have the usual club features. In the basement there is a large swimming pool and shower baths, bowling alleys and locker rooms. The first floor will be devoted mainly to a general lounge, reading room and library, with one large room set apart for a gymnasium. On the second and third floors there are thirty-three living rooms that will be furnished and rented to single men in the company's employ, exclusive of the members of the technical staff for whom quarters have already been provided. The average monthly rental will be about $10 per room. A few of the rooms have private bath, but on each floor there is a large bath and toilet room for general use.

The club will be for the use of all employees without distinction or restriction except as to hours designated for certain groups of men and members of their families. The establishment of this club is an evidence of the growing sentiment in favor of welfare work among the employees of large companies, especially in isolated places where opportunity for recreation is limited.

EMPLOYEES' CLUB HOUSE, NEVADA CONSOLIDATED COPPER COMPANY

Weidlein's Copper Process

Some interesting experimental work in copper hydrometallurgy is in progress at the Mason Valley smelter at Thompson, Nev., under the direction of Dr. E. R. Weidlein. Particular novelty rests in the method of precipitating copper from solution and in the concentration of sulphur dioxide from smelter fume or other dilute sulphurous gases.

The method of treatment is applicable to either carbonate or sweet-roasted sulphide ores of copper. Sulphuric acid is the solvent used. Ore that is readily leachable is treated in vats; but for finer material a six-step Dorr classifier has been used with countercurrent flow of solution.

Before precipitation the solution is neutralized with lime and treated with sulphur dioxide until it has dissolved a percentage of gas equal to that of the contained copper. Precipitation of metallic copper ensues instantly when this solution is brought to a temperature of 160 deg. C. under a pressure of 100 lb. The precipitated metal is finely crystalline and when melted assays over 99 per cent pure. In the process of precipitation, sulphuric acid is regenerated in twice the quantity originally present in combination with copper:

$$CuSO_4 + SO_2 + 2H_2O = Cu + 2H_2SO_4.$$

The mechanical arrangements are such that the processes of dissolution and precipitation are continuous. Heat is conserved by returning the hot precipitated solution through a heat exchanger in counter current to the flow of fresh solution to the precipitator. The latter is a lead-lined cylinder through which the solution flows from bottom to top. The necessary temperature is obtained by circulating oil of high flash-point from a heater through the jacket surrounding the lead lining. Precipitated copper is discharged through a bottom gate into a receptacle from which it is periodically removed, washed and melted.

An interesting development of Dr. Weidlein's research, and one of prospective economic importance, is a process of concentrating the sulphur dioxide from smelter fume or other gases weak in that constituent. The details of the method are not now available, but it depends on the principle of selective absorption in a tower packed with the absorbent. The gas can be driven from the absorbent by heat and used as desired.

Some of the research work in connection with this process has been conducted at the Mellon Institute, Pittsburgh, in conjunction with the large-scale experimental work at Thompson, Nev. The investigations have been carried on in a careful and scientific manner, and the announcement of results will be awaited with interest, in view of the probable future importance of hydrometallurgy for low-grade, oxidized ores of copper.

First-Aid Field Meet at San Francisco

The contests in first-aid and rescue work held at the Exposition grounds in San Francisco, Sept. 22, 23 and 24, formed an interesting feature of "Mining Week" at the Exposition. Twenty-six first-aid teams and fifteen mine-rescue teams were entered, representing eighteen States. The contest events were selected by the judges from lists that had been previously placed in the hands of the teams for practice purposes. In first-aid there were events for one man, two and three men and full team. For coal-mine rescue events an explosion was simulated in an improvised gallery. The meet was financed by the California Metal Producers Association, which subscribed $1,500. Prizes for successful contestants included silver cups, silver and bronze medals, and miscellaneous donations from numerous manufacturers.

American Mining Congress

The eighteenth annual session of the American Mining Congress was held at San Francisco, Sept. 20-22, to receive reports of important committees and discuss topics of interest to the mining industry. Mr. Van H. Manning, director of the Bureau of Mines, outlined the past services of the Bureau to the mining industry and suggested a number of lines of metallurgical research in which work will be done in the near future. Among some of these problems are the recovery of platinum and allied metals, the improvement in recovery of zinc from low-grade ores, and the development of our resources in tin, chromium, manganese, antimony and molybdenum, by improving methods for handling low-grade material. Dr. George Otis Smith addressed the Congress on the subject of "Plain Writing," with a plea for fewer razor-edged words in technical writing, suited only to hair-splitting technicalities. The subject of mining and metallurgical education also received attention in a paper by Prof. Charles F. Willis of Tucson, Ariz. The balance of the program was devoted to business and economic aspects of mining.

Memorial exercises in honor of Dr. Joseph A. Holmes, late director of the Bureau of Mines, were held at noon, Sept. 21.

The Iron and Steel Market

Another month's developments in the course of the iron and steel market has indicated still more conclusively that the backbone of the steel demand is the requirements for war purposes. The war demand has continued to increase, and as fresh orders for large tonnages are placed from day to day, while purchases formerly made were for extended deliveries, the output of war material is steadily increasing.

The general alignment of demand has become more clearly defined. In no finished steel product is there a large domestic demand. For war purposes there is a very heavy demand for wire products, for large steel rounds and for forging billets. Inasmuch as the large rounds are rolled on rail mills, enabling the rail mills to consume more steel than for many years, while the large tonnage of forging billets demanded requires no finishing operation by way of rolling, a condition has arisen by which there is great pressure for tonnage upon the steel-making departments, and only occasional pressure upon finishing mills. At the same time it develops that there is ample pig iron for the requirements of Bessemer converters and open-hearth furnaces. There results what is called in trade parlance "a scarcity of steel." Rolling billets are scarcely to be obtained at $26 at mill, per gross ton, when bars, plates and shapes are quoted at $27 per net ton, and forging billets have brought $35 and more. Between basic pig iron at valley furnace and basic open-hearth billets at valley mill there is a spread of fully $11 per ton while last December the spread was only about $5.

The entire open-hearth steel-making capacity of the country is in full employment, and practically the entire Bessemer capacity. The small Bessemer plant at Columbus is idle, and at a few Bessemer plants operations are not at the fullest rate possible, but such instances are exceptional. The steel trade has thus far supplied itself with pig iron without drawing nearly as much upon the merchant furnaces as in 1912 or 1909, periods in which the pressure for steel was scarcely as great as at present. Upon coke there has been no pressure at all, doubtless by reason of the large increase in coke-making capacity of late through the erection of retort plants. The demand in the market for scrap is not heavy and scrap is selling at lower prices than are usually current when billets bring their present prices. The situation doubtless is a reflection of the large ingot cropping required in the filling of many of the war orders.

All the consuming industries in the United States show a better demand for finished steel products than two or three months ago, but in no instance is the demand up to previous high levels unless the industry is engaged more or less in the production of war material. In a general sense export and war orders are synonymous, for the purchases of neutral countries are still below normal. Agricultural implement exports, while heavier than six months or a year ago, are distinctly below normal. In the machine tool and automobile industries there is feverish activity as, of course, is the case at munition factories. Exports direct and indirect are probably now consuming finished steel at the rate of more than 5,000,000 tons annually.

Pig Iron

Pig iron prices advanced about one-half as much in September as in August, and the September advances were due more to the sold-up condition of the furnaces than to any large demand. There was very little buying by foundry interests, and no general buying by steel works, though a few large blocks were taken. The condition at the close of September is that consumers appear to be well covered against requirements through the remainder of the year, with the furnaces now in operation equally well sold up, and neither buyer nor seller anxious to force conclusions as to deliveries in the first half of the new year. A buying movement for that delivery is hardly expected before late October or early November. While the steel works are producing more steel than ever before, and the steel interests are making more pig iron than ever before, the merchant blast furnace output is considerably less than the capacity. The idle merchant furnaces are not finding occasion to blow in as rapidly as was expected and thus buyers of pig iron feel fairly well insured, at least for the present, against a runaway market.

Shipments of Lake Superior ore down the lakes amounted to 26,806,420 tons for the season to Sept. 1, or less than in the corresponding period of several preceding years, but estimates of the movement for the remainder of the season are made as high as 22,000,000 tons and if such expectations are realized the year's movement will closely approximate the record. There is no danger of anything like a general ore shortage, though buyers seeking particular descriptions of ore, especially for the open-hearth furnace, have lately had a little difficulty in effecting purchases. Pig iron is quotable as follows: No. 2 foundry delivered Philadelphia, $16.25 to $16.75; f.o.b. furnace, Buffalo, $15.50 to $16; delivered Cleveland, $15.25; f.o.b. furnace, Chicago, $14.25 to $14.75; f.o.b. Birmingham, $11.50 for prompt, $12.50 for first half 1916; at valley furnaces, 95c. higher delivered Pittsburgh: Bessemer, $16; basic, $15; No. 2 foundry and malleable, $14.50 to $15; gray forge, $14.25 to $14.75.

Steel

To the insistent demand for rolling billets that characterized August, with a moderate demand for forging billets, there has succeeded a very heavy demand for forging billets. Billets are so scarce in general, and prices that can be secured for special steels are so attractive, that the market for ordinary soft steel rolling billets is scarcely quotable at all. There is no question that $26 at maker's mill, Youngstown, would readily be paid for ordinary open-hearth billets, and Bessemer billets might easily bring $25, prices delivered Pittsburgh being $1 a ton higher, as no steel to speak of is being offered by Pittsburgh mills. Sheet bars would not be sold except at the full billet price or a trifle more, but there is no demand whatever. The sheet and tin mills are covered by contracts, and in any event the selling prices of their products are such that they could not afford to buy steel at prices that would be asked. Wire rods are quotable at $30, Pittsburgh, but sellers can scarcely be found at any price.

Finished Steel

Wire products were advanced $2 a ton Sept. 20. Effective Sept. 28 the American Sheet & Tin Plate Company advances its prices $2 a ton on blue annealed and black sheets, to 1.6c. for blue annealed, 2c. for Bessemer black and 2.05c. to 2.1c. for open-hearth black. Bars, plates and shapes for delivery at mill convenience have been 1.35c., for 1.40c. has been quoted and done on first quarter contracts and the mills have little left to sell for earlier delivery so that the market promises shortly to be squarely on the basis of 1.4c.

Current quotations, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard section, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.35c. to 1.4c.

Shapes, 1.35c. to 1.4c.

Steel bars and bands, 1.35c. to 1.4c., base; hoops, 1.5c., base.

Iron bars, 1.45c. to 1.5c., Pittsburgh; 1.509c. to 1.559c., Philadelphia; 1.35c., Chicago.

Sheets, blue annealed, 10-gage, 1.55c. to 1.6c.; black, 28-gage, 2c. to 2.1c.; galvanized, 28-gage, 3.5c. to 3.6c.; painted corrugated, 28-gage, 2.2c.; galvanized corrugated, 28-gage, 3.55c. to 3.65c.

Tin plate, $3.10 to $3.20 for 100-lb. coke.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 63½ per cent off list.

Steel boiler tubes (less than carloads) 72 per cent off list.

Structural rivets, 1.6c.; boiler rivets, 1.7c.

Railroad spikes, 1.5c., Pittsburgh; 1.65c., Chicago.

The New Director of the Bureau of Mines

Mr. Van H. Manning has been appointed Director of the U. S. Bureau of Mines, as successor of the late Joseph A. Holmes. During Dr. Holmes' administration of the bureau, Mr. Manning was Assistant Director. Before entering the Bureau of Mines he was connected with the U. S. Geological Survey. The good wishes of the profession and the industry are due to Mr. Manning on his entrance into a position of grave responsibilities and great opportunities.

San Francisco Meeting of American Electrochemical Society

The twenty-eighth general meeting of the American Electrochemical Society was held in San Francisco from Thursday to Saturday, Sept. 16 to 18. The attendance was comparatively small on account of the scarcity of local members and electrochemical industries in California, but it came up to expectations, and those who were present enjoyed the meeting immensely.

At the Board of Directors meeting routine business was transacted and it was decided to hold the Spring meeting, 1916, at Washington, D. C.

The technical session of Thursday morning was opened by President Addicks and the papers by Wills and Schuyler, Snyder, Mott, Aldrich, Betts, Bennet, Rose and Tinkler, Frederiksen, Bancroft, and Bosworth were read and briefly discussed.

On Friday two sessions were held as planned. In the morning session held jointly with the American Institute of Mining Engineers, the papers by Lyon and Keeney, Clevenger, Addicks, Wile, Boeck, Davy, Goodrich and Pyne were read and discussed at some length.

The afternoon session was held in conjunction with the American Institute of Electrical Engineers and the papers by Foster, Sebast, and Beckman were read and discussed.

We reserve a full account of all the papers and discussions for our next issue.

A pleasing feature of the meeting was the session at which the Exposition medal was presented to the Society. Mr. Chas. Butters presided on this occasion. Mr. Chas. A. Vogelsang presented the medal.

President Addicks accepted the medal with a short address in which he referred to the westward trend of electrometallurgy. He traced the historical development from the invention of the dynamo with its effect on mechanical and electrical engineering and on chemistry and metallurgy to the ultimate birth of electrochemistry as a distinct science and industry which necessitated the formation of a new society for growth and expansion. Electrochemistry has played an important part in the industrial progress of recent years, which the San Francisco Exposition expresses on such a magnificent scale. The presentation of the medal was followed by special visits to the exhibit of the Bureau of Mines and the Norway exhibit of nitrate products.

All social functions were carried out according to the program and greatly enjoyed.

San Francisco Meeting of American Institute of Mining Engineers

The 111th meeting of the American Institute of Mining Engineers, held in San Francisco from Sept. 16 to 18, was most successful. The attendance was large in the technical sessions as well as at all social functions. Great credit is due to the different committees and their chairmen, Merrill, Hanks, Shockley, Clevenger, for the excellent arrangements made. An elaborate souvenir program with artistic illustrations of California and the Exposition had been prepared. All meetings were held at the Bellevue Hotel.

At the opening meeting on Thursday morning in the Palm Room of the Bellevue Hotel, C. W. Merrill presided. An address of welcome to California was made by Arthur Arlett. President Saunders replied for the Institute. Dr. L. D. Ricketts then presented his address on some problems of copper leaching. A. J. Clark spoke on Homestake metallurgy, and F. L. Bosqui on gold metallurgy in the Witwatersrand district. The latter paper brought out considerable discussion of a reminiscent nature from former Rand operators.

In the afternoon session on gold and silver F. Lynwood Garrison presided, and papers by C. W. DeWitt, W. P. Lass, E. E. Carpenter, N. Herz, E. B. Thornhill, J. A. Carpenter, W. J. Sharwood and A. H. Jones were read. Simultaneously a session on geology and mineralogy was held, Andrew G. Lawson presiding.

On Friday morning a joint session was held with the American Electrochemical Society, Lawrence Addicks presiding. Simultaneously there was a session on petroleum and gas, with Arthur F. L. Bell in the chair. In the afternoon there was a session on mining, milling and non-ferrous metallurgy.

Abstracts of the papers and discussions are reserved for our next issue.

On Friday afternoon the Exposition medal was presented by the Exposition authorities to the Institute. President Saunders accepted the medal with a felicitous speech.

The banquet on Friday night at the Palace Hotel was a brilliant affair, attended by some three hundred members and friends of the Institute. The occasion was graced by the presence of many ladies. Mr. E. H. Benjamin acted as toastmaster and speeches were made by Benjamin Ide Wheeler, "An Engineer"; W. L. Saunders, "California"; Van H. Manning, "Co-operation"; George Otis Smith, "The Outlook," and T. A. Rickard, "The Ladies."

On Saturday morning a boat trip was made around San Francisco Bay on the private yacht Cyprus, by courtesy of Mr. D. C. Jackling. A stop was made at the Selby Smelter, where the blast furnaces, the Parkes refining process, the Cottrell process for precipitation of sulphuric acid fume from parting vats, the filtration of smelter gases in a bag house and the manufacture of special lead products were shown. For Sunday afternoon Mr. and Mrs. Charles Butters had invited the Institute to their Oakland home for a lawn reception and tea, and inspection of laboratories and testing plant.

The Institute may be proud of the great success of this meeting.

Metallurgy at International Engineering Congress

San Francisco, September 20 to 25, 1915

The International Engineering Congress, held at San Francisco from Monday to Saturday, Sept. 20 to 25, 1915, was a great success from start to finish.

At the opening session on Monday the attendance was 800, with a good representation from foreign countries.

Mr. W. F. Durand, chairman of the organization and managing committee, opened the Congress with a review of the four years of work, the object of which was now being realized. The local committee had corresponded with 250,000 engineers and 250 engineering societies. Although the European war had threatened to impair the success, the value of the Proceedings of the Congress has not been impaired in any way. Two hundred papers have been printed in advance; thirty more papers are yet to be printed. The Proceedings of the Congress will fill eleven volumes of 7000 pages, and the authors will represent eighteen countries. Mr. Durand concluded by introducing the Honorary President General Goethals, who, after acknowledging the honor, introduced the Mayor of San Francisco.

Mayor James Rolph, Jr., welcomed the Congress to San Francisco and paid a high tribute to all classes of engineers for constructive work on the Panama Canal, of which San Francisco is the chief beneficiary.

President Charles C. Moore of the Panama-Pacific Exposition said this Congress was by far the most important of 880 different conventions held in connection with the Exposition and expressed the hope that the deliberations of the Congress would result in vast good for humanity.

General Goethals then made his formal address on the Panama Canal and the Panama-Pacific Exposition. The completion of the canal was possible only through the coöperation of all classes of engineers and scientists. Incidentally it proved that engineers are fitted for great executive administrative work when politics is eliminated.

Brief responses to the address of welcome were made by the delegates of Sweden, Switzerland, France, Cuba, China, Japan, Netherlands, Nicaragua, Spain, Canada and Guatemala.

The presentation of the John Fritz medal to Dr. James Douglas, which was to conclude this session, had to be postponed on account of the illness of Dr. Douglas.

The real work of the Congress was carried out, of course, in the different sections. In the following we report the proceedings in the Section on Metallurgy:

TUESDAY SESSION

The first session of the Metallurgical Section was held on Tuesday afternoon, Prof. Richards presiding. It was almost completely devoted to the Symposium on Iron and Steel.

Symposium on Iron and Steel

The Symposium on Iron and Steel had been arranged and edited by Dr. Henry M. Howe.

The first paper presented related to **iron and steel castings,** the author being Mr. John Howe Hall of the Taylor-Wharton Iron & Steel Co. of High Bridge, N. J. Iron and steel castings may be made either of steel or of malleable iron or of cast iron. According to the general nature of the three metals, the castings have distinct fields of usefulness.

The variations in the properties of steel castings are due (1) to variation in the composition of the steel, (2) to the annealing or heat treatment to which the steel is subjected, and (3) to the soundness of the casting.

The soundness depends on the degree to which blowholes or shrinkage cavities can be avoided. As to composition the effect of carbon, silicon, manganese, phosphorus and sulphur was discussed, also the effect of annealing and heat treatment on steels of different composition.

The method by which the steel is made influences its properties largely by its effect upon the composition that it is possible to secure and upon the tendency of the steel to unsoundness. The extent to which the steel is subjected to oxidation during its manufacture influences the tendency to unsoundness. In general, the Bessemer process oxidizes the steel to the greatest extent, the open-hearth process to a less degree, the crucible process to a still less degree, and the electric furnace process least of all.

The process by which the steel is made is, in many cases, of less importance that the skill and knowledge of the workmen, so that the purchaser is better protected by calling for metal of good properties as exhibited by tests than by buying castings made by some particular process that he supposes to be the best. Even electric-furnace steel is subject to this statement. The growing use of the electric furnace in steel foundries is due as much to the fact that it possesses certain technical advantages for the manufacture of high-grade small castings as to the superior excellence of the steel made in it. "The electric furnace, so far, has been used in competition with the Bessemer and crucible processes in making light work, for which it has certain marked advantages. One may hazard a guess that its chief application in the future will be in this field, and that its use for heavy work will be confined to a limited number of cases where steel of very high quality is required."

Malleable iron castings and cast iron castings were finally briefiy discussed.

"The best way to secure satisfactory castings is to prescribe the tests that the metal must meet—such as strength, ability to withstand a certain hydraulic pressure without developing leaks, machinability, etc.—and leave the composition to the maker, who can generally be depended upon to choose the composition best suited to the requirements. The maximum sulphur, and sometimes phosphorus, content, may be specified, but the engineer should be careful not to go so far in this line as to unnecessarily embarrass the foundryman."

In the discussion which followed, Mr. Bechman said the trade term "semi-steel" should be eliminated, as it offered a chance for imposition on the consumer by suggesting something better than the actual product. The possibility of including radiographic tests of castings in the specification was pointed out.

Metallography and the Hardening of Steel was the subject of a paper by Dr. Albert Sauveur of Harvard University. The influence exerted by metallography on the elucidation of the still much debated question of the causes underlying the hardening of steel was pointed out. The author discussed the phlogiston theory, Percy's explanation, Akerman's compression theory,

Howe's explanation in 1890, early tension or stress theory, Osmond's allotropic theory, the stress theory again, Le Chatelier's theory, Arnold's subcarbide theory, McCance's interstrain theory, Humphrey's amorphous theory, and Carpenter's and Edwards' twinning and amorphous iron theory.

The many recent attempts at arriving at a satisfactory explanation of the hardening of steel are based on one or more of the following conceptions (1) existence of a hard allotropic variety of iron, (2) existence of solid solutions involving the occurrence of so-called "hardening" carbon, and (3) existence of strains in quenched steel causing or not an amorphous condition in the iron. No theory so far presented fully satisfies our craving for a scientifically acceptable explanation of the many phenomena involved.

"It would seem as if the methods used to date for the elucidation of this complex problem have yielded all they are capable of yielding, and that further straining of these methods will only serve to confuse the issue, a point having been reached when this juggling, no matter how skillfully done, with allotropy, solid solutions, and strains is causing weariness without advancing the solution of the problem. The tendency of late has been to abandon the safer road of experimental facts and to enter the maze of excessive speculations, in which there is great danger of some becoming hopelessly lost. The conclusion seems warranted that new avenues of approach must be found if we are ever to obtain a correct answer to this apparent enigma."

The discussion of this paper showed that the consensus of opinion was in favor of Le Chatelier's theory, although it was admitted that it would not explain all varieties of steel. Radiography was again suggested as a possible new method of attack to distinguish between different steels.

The Recent Progress and Present State of the Technical Application of the Case Hardening of Steel was the subject of a long paper by F. Giolitti, Director General of the Steel Works, Gio. Ansaldo & Co. of Genoa, Italy. The author first discusses the present condition of our theoretical knowledge of the process of case-hardening of steel. He then deals with the characteristics of the various carburizing substances and their use. He favors "gradual" agents, the activity of which is due exclusively or in absolutely preponderant degree to the specific action of carbon monoxide, as distinguished from "abrupt" agents (nitrogenous organic substances, hydrocarbons, cyanides and ferrocyanides).

"Gradual" agents are powdered or granular charcoal, calcined lampblack and calcined bone charcoal; further mixtures of powdered or granular charcoal with carbonates which are dissociated at high temperature ("Caron's cement"; sixty parts of powdered wood charcoal mixed with forty parts of pulverized carbonate of barium); further granular wood charcoal through which is circulated a more or less slow current of carbon monoxide. With the last agent the action of the carburizing substance may best be regulated.

The author then gives illustrated descriptions of the arrangement for the use of various types of carburizing materials and finally discusses the treatment and the characteristic properties of cemented parts.

There was no discussion of this paper.

The Duplex Process of Steel Manufacture was the subject of a paper by Mr. F. F. Lines of the Maryland Steel Company, Sparrow's Point, Md. The author discusses the combination of the acid Bessemer and the basic open-hearth. The acid converter oxidizes the silicon, together with the manganese and a certain portion of the carbon, the exact amount depending upon the practice. The blow metal is then transferred to the basic open-hearth furnace where the phosphorus and the remainder of the carbon is removed. The duplex process shortens the open-hearth purification by more than five-sixths of the usual period, giving a steel of the same quality as the straight open-hearth process. Some details of operation in practice and results are given in the paper.

In the discussion of the paper, Dr. Richards said that this process was only one of many possible variations of duplexing. He expected a wider use of combination methods, using the most economic features of the Bessemer, the open-hearth, and the electric processes in combination.

Methods of Preventing Piping in Steel Ingots was the subject of a paper by Mr. Emil Gathmann of Baltimore, Md. After a brief discussion of Hadfield's and Kennedy's methods, the author said that an ingot with its larger horizontal cross-sectional area at the top is without question the best shape for obtaining the important so-called "lag" in solidification of the steel, and whenever such large-end-up ingots can be conveniently used, it is the best practice to do so. Another method of the author is now being tried at one plant of the U. S. Steel Corporation. He uses ordinary big-end-down ingots, but designs the mold so that the lower 70 or 80 per cent of the metallic mold in which the ingot is cast has a much greater degree of heat absorptive quality than the upper 30 or 20 per cent. (Fig. 1.) A metallic mold with heavy lower body walls and thin upper walls, *per se*, properly designed, will produce a sound homogeneous ingot with about a 20 per cent top crop in split ingots of dead killed steel, which is about 15 per cent less than is usually necessary in cropping cold ingots made in the old type of mold of like grade of steel.

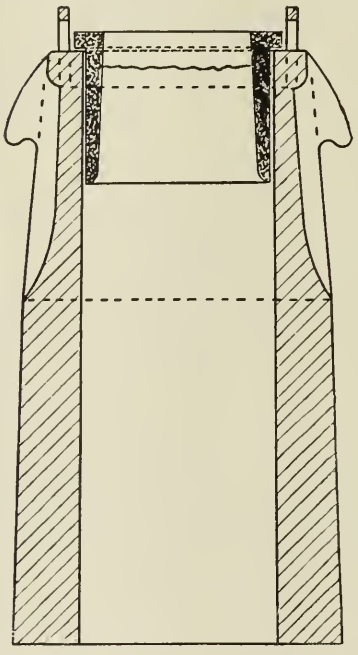


FIG. 1—GATHMANN MOLD

In the discussion of the paper the importance of following sound metallurgical principles in thorough degasification of molten steel regardless of the method of producing the ingot was pointed out.

Steel Alloys was the subject of a paper by George L. Norris of Pittsburgh, Pa. The paper gave compositions and special uses of steels alloyed with manganese, silicon, nickel, chromium, vanadium, tungsten, and cobalt.

Steel Making in the Electric Furnace was the subject of a paper of Mr. James H. Gray of the U. S. Steel Corporation. The electric furnace is a new instrument for steel-making, as it has a neutral and even reducing atmosphere as distinguished from the oxidizing atmosphere of all other steel furnaces.

Upward of 150 electric steel furnaces have been installed in many different countries. The largest unit so far is twenty tons.

"Electric steel is now extensively used for products as tires, axles, seamless tubes, and small castings. The

fact that electric steel lends itself to heat treatment more readily than other kinds of steel, both as regards greater range of temperature and absence of cracking in the quenched piece, and that there is less loss due to defective material after machining in the machine shop also gives this steel a preference even at a higher price.

"Many have doubted if electric steel can ever be made for such low-priced products as rails and structural material so as to compete with open-hearth steel. I believe that the solution of this problem depends upon the adoption of the proper combination process by which the roughing down work will be done by one or several of the older methods using cheap fuel, and the finishing or final refining done in the electric furnace. Both the acid and the basic Bessemer and the open hearth have been used to supply molten metal to the electric furnace. The finishing has been done in both basic and acid electric furnaces.

"In the basic electric furnace both dephosphorization and desulphurization can be performed, and it can be supplied with a metal only partially refined, while the acid electric furnace should be supplied with a metal from which both phosphorus and sulphur have been removed, requiring greater preliminary refining—going back even to the blast furnace.

"During the last two or three years rapid strides have been made with the duplex or Bessemer open-hearth process, and costs are being obtained which compensate for the excessive metal loss in the Bessemer part of the process. It may be that the duplex process in connection with either the basic or acid electric furnace will give us the solution. However, enough has already been done with the manufacture of the heavier or lower priced products to indicate that, provided it is turned out in producing units of equal size, the total cost of electric steel will be near enough to that of open hearth steel, so that the manufacturer can afford to stand the difference in order to give the consumer quality, the requirements for which are constantly growing more rigid.

"The possibility of bringing the cost of the two steels near together will appear more feasible if we consider such incidental savings as the use of cheap pig iron at the beginning of the process and the smaller discard of rolled product due to having an ingot free from segregation.

"In Germany, Luxembourg and eastern France, the electric furnace is the best apparent solution of a condition which is a menace to the steel industry of those countries.

"While the high phosphorus ores of Luxembourg and Lorraine, together with the basic Bessemer process, made possible the great steel development of Germany, the quality of basic Bessemer steel does not to-day give it a standing with open-hearth steel, while the demand for better quality is daily growing. On the other hand, basic Bessemer steel, after refining in the electric furnace, is superior to open-hearth steel. The manufacture of electric steel by this method was began in Germany several years ago, and has in moderate quantities been made into all kinds of steel products. It seems probable that the American steel manufacturer will find it necessary to adopt electric steel to meet the competition which he will meet in the world's markets.

"It has been remarked that the progress of electric steel manufacture in America has been slow as compared with that in Europe, but the indications are that this relation will soon be reversed. It was natural that the invention of the electric furnace should be made in countries where cheap hydro-electric power was already in extensive use for other electro-chemical processes, but it was only a couple of years before the first electric furnace was installed in the United States. We must also remember that the first large furnace, namely, one of fifteen tons' capacity, requiring electrodes 2 ft. in diameter, a then unheard of size for steel furnace use, was built here; also that this furnace was the first to use three-phase electric current, which adapted it to utilize the kind of current in general commercial use.

"There are now either built or building over forty electric furnaces in America, of which there are twenty-seven of the Heroult type alone. The average size of these furnaces is also greater than the average size in Europe.

"If the electric furnace be used for the further refining of steel made in present installations of the older processes, as now seems probable, the amount of electric steel produced should then eventually be commensurate with that now being produced by those processes; and it follows that electric steel production in the United States will exceed that of any other country."

In the discussion Mr. Beckman said that the manufacture of electric steel castings is possible at the Pacific coast, while duplexing is not possible in view of the lack of open-hearth and Bessemer plants. One hydro-electric development at the Pacific coast is able to supply 600,000 hp. continuously.

Mr. Babcock questioned the cheapness of hydro-electric power on account of the expense of the first installation and the fluctuation of the available water. He thought steam power to be cheaper but too expensive for electric furnace operation.

Mr. Beckman replied that castings are now made in the electric furnace in San Francisco, Portland, Seattle, and Los Angeles, and that four new plants are projected.

Electrometallurgy was the subject of the last paper of the session, the author being Dr. E. F. ROEBER, editor of "Metallurgical and Chemical Engineering." The author first deals with electric furnace processes, giving the fundamental principles and a classification, and discussing the chief metallurgical applications of electric furnaces for melting and refining (steel) and for reduction processes (ferro-alloys, iron, zinc). The second chapter deals with electrolytic processes; after a statement of the fundamental principles and a classification, the author discusses commercial applications of electrolytic processes with soluble anodes (electroplating, electrolytic refining of copper, silver, gold, lead, nickel, zinc, iron, tin, bismuth, cadmium) and of electrolytic processes with insoluble anodes (electrolytic precipitation of gold in cyanide process and of copper in copper leaching processes). The third part of the paper deals with electrolytic furnace processes (aluminium, sodium, magnesium, calcium, cerium, zinc).

In the discussion of the paper the possibilities of electric smelting of California complex ores was suggested.

THURSDAY SESSIONS

Symposium on Copper

The second and third sessions of the Section on Metallurgy were held on the morning and afternoon of Thursday, September 23, Dr. L. D. RICKETTS presiding.

Both sessions were devoted to the Symposium on Copper, arranged and edited by Mr. E. P. MATHEWSON, of the Anaconda Copper Mining Co.

The first paper on the program was a general statement of **Progress in Copper Metallurgy**, by THOMAS T. READ. The author reviews the shifting changes that have occurred to meet new conditions, and the resulting interest in different phases of copper metallurgy at different periods. Blast-furnace smelting developed

to its height when the mines were producing suitable high-grade sulphide ore in lump form. With the development of low-grade ore bodies and the methods of concentrating them, roasting and reverberatory-smelting furnaces became improved, and the advance in this art left blast-furnace smelting in the background. With this came the successful use of the basic lining for converters, which improved and simplified general smelting practice as well as converting itself. Later, hydrometallurgical processes received a great deal of attention, with resulting notable progress in the wet treatment of low-grade ores and tailings. This work is still in progress and, in the opinion of the author, may exert a profound effect on the metallurgy of copper.

In the discussion of this paper Dr. RICKETTS said the dust losses in reverberatory smelting likely increase with the treatment of fine flotation concentrates and must receive attention. The increase of leaching processes raises the problem of the disposal of waste acid liquor.

Advances in Copper Smelting was the subject of a paper by FREDERICK LAIST of the Anaconda Copper Mining Co. The author regards the rapid growth in favor of reverberatory as compared with blast-furnace smelting as the most notable difference between practice in the past ten years and the ten years preceding. He assigns the following reasons: The lengthening of Anaconda reverberatories together with the semi-continuous method of operation, and the reduction of cost of reverberatory smelting to the level of blast-furnace smelting; introduction of oil firing; success of pulverized coal firing; and the remarkable success of the flotation process in making high recoveries, so that concentration followed by reverberatory smelting is more profitable than direct smelting, even on comparatively high-grade material. At Anaconda, for example, the direct smelting of first-class ore is to be stopped, and all ore will be concentrated and smelted in reverberatories. This will result in economies due, in part, to the fact that reverberatory smelting with pulverized coal will be cheaper than blast-furnace smelting, and, in part, to the elimination of barren flux which must be used in blast furnaces.

Basic lining for converters has revolutionized converter practice, and it has been demonstrated that practically any size or shape of converter shell can be successfully lined and operated as a basic converter. Many of the refinements originally considered essential are not considered of vital importance. The main considerations for successful operation are (1) avoidance of too high temperature, and (2) the maintenance of a coating of magnetite over the bricks.

No radical changes of importance in blast-furnace smelting have occurred, except the building of the long furnaces by E. P. Mathewson. The use of hot blast has been abandoned. The development of the turbo blower for pressure up to 16 lb. per sq. in., may result in the displacement of the Root type of blower for blast furnace and converter air.

The McDougall type of roaster holds its place as a roasting furnace as well as a preheater for reverberatory charges where the quantity of sulphur is low and a hot-fry material is desired.

Bedding systems are growing in favor, especially where materials of diverse character are being smelted.

More attention is being paid to dust losses and the purification of smelter gases. Bag houses and the Cottrell system of electric precipitation are successfully used.

The author gives a bibliography of copper-smelting literature and brief comment on details of the foregoing general statements.

Dr. Cottrell spoke of the effect of temperature on electrostatic precipitation and fractional separation of fume constituents by regulation of temperature. Lower voltage is used at high temperatures since the dielectric strength decreases with increase in temperature.

Dr. Ricketts said that unaccountable losses in smelting suggested the necessity of studying possible constant errors in sampling which would explain such losses.

Mr. A. E. Wells mentioned an instance of faulty moisture sampling of concentrates at a smelter, which resulted in an apparent increase of the plant copper loss by 40 per cent.

Mr. E. A. Hersam pointed out the need of more data on converter slags and linings, on the temperature of slag formation, and the composition of the acid material added to the converter.

Replying to questions Mr. Laist said that basic converting could be successfully carried out in small plants since converters could be used only for one shift daily if necessary. The basic converter stands hard usage with surprisingly little cracking of the lining due to expansion and contraction. The prospective shortage of Austrian magnesite caused the Anaconda experiments with other materials. California magnesite was found fairly satisfactory giving half the life, while chrome brick gave one-fifth the life of Austrian magnesite.

Mr. R. H. Bradford inquired concerning the possibility of sintering raw concentrates and leaving enough sulphur for blast smelting.

Mr. Laist explained that it was rather difficult to sinter high-sulphur material, on account of the clogging of the grates and distillation of sulphur. But even if Mr. Bradford's suggestion could be carried out, the cost of sintering plus blast smelting is greater than the cost of roasting and reverberatory smelting.

Metallurgy of Copper in Japan was the subject of a paper by Mr. R. KONDO, Director of the Furnkawa Co., Tokyo, Japan. It reviewed the progress of copper metallurgy in Japan since the earliest days of the Mabuki converting process. The present Japanese copper plants use modern processes of sintering, smelting, and electrolytic refining. The smoke problem is acute in Japan on account of the congested population and the bad effect of the sulphur fumes on rice.

Copper Metallurgy of the Southwest was the subject of a paper by Dr. JAMES DOUGLAS, reviewing the history and development of copper metallurgy in the southwestern states. Evidences of copper metallurgy in prehistoric times in this part of the country may be seen in the copper hammers found in shallow pits on carbonate mines. Later, adobe furnaces were used, the remains of which still stand near the Hanover mines. Apart from these primitive efforts, the first important copper mining and reduction occurred about 1872 when the Longfellow and Coronado mines were opened at Clifton and the ores smelted in furnaces of different types; first, reverberatories; then adobe stacks, and finally copper-jacketed furnaces. The latter were still used as late as 1881.

Work at the Copper Queen began in June, 1880, with a 36-in. iron-jacket furnace for smelting. A second stack of this type was erected and the plant turned out for the original Copper Queen Mining Co., from 1880 to 1885, a total of 34,536,000 lb. copper from ore averaging 11.5 per cent copper. Fortunately the mines of the Bisbee district yielded an oxidized ore of fusible composition, and slag losses were low, being about 2½ per cent. In the Clifton and Globe districts, on the other hand, where the ores were silicious and required as much as 50 per cent barren flux to render them fusible, the slags ran from 3½ to 4½ per cent copper. The introduction of Bessemer converting at the Copper

Queen in 1893 was necessitated by the increased sulphur in the deeper ores. The furnace yield increased 1½ per cent and the grade of Bessemers to 99 per cent, fitting them for electrolytic refining.

When the new Copper Queen works were erected in the Sulphur Spring Valley, many changes and improvements were made. The blast furnaces were enlarged; basic-lined converters were adopted; a roasting and reverberatory department was added.

The most notable change in copper smelting in the southwest, as elsewhere, has been the substitution of reverberatories for blast furnaces, in order to smelt the increasing quantity of concentrates offered. At the new plant of the Arizona Copper Co., Clifton, and the American Smelting & Refining Co., Hayden, reverberatories are used exclusively. The new plant of the International S. & R. Co., a flow-sheet of which is shown in Fig. 1, will also have reverberatories for treating the concentrates from the Miami and Inspiration mines. These furnaces will be 21 ft. by 120 ft., and the concentrates to be smelted will contain approximately 40 per cent copper, so that their production will exceed that of any other Arizona smelter. In conclusion, Dr. Douglas gives an outline of the equipment at Arizona smelters.

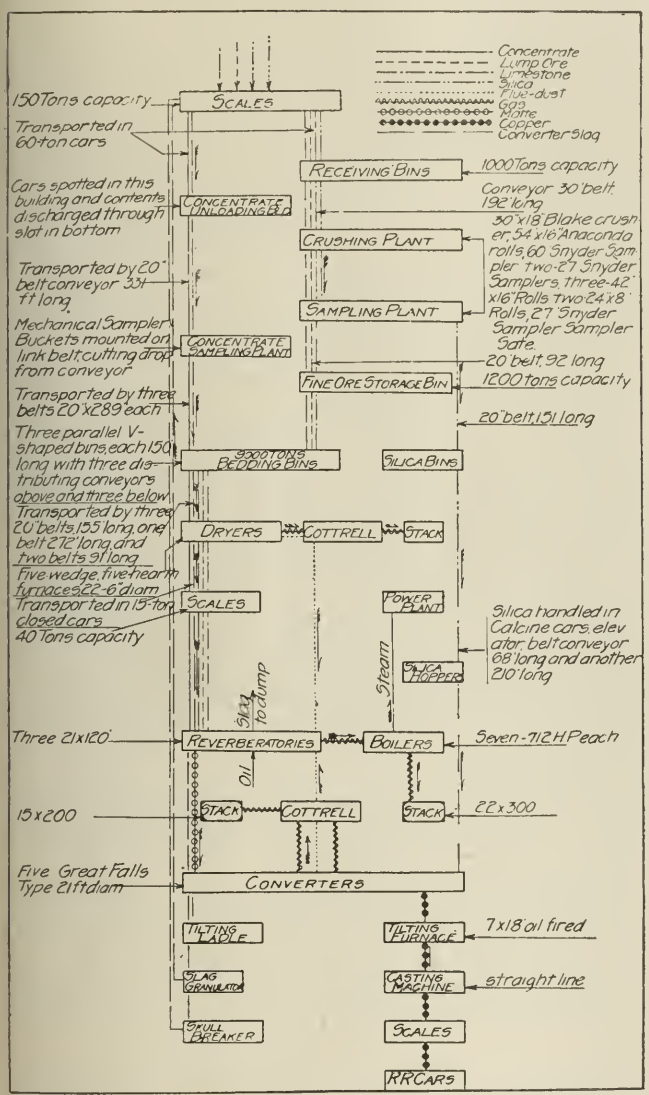


FIG. 1—FLOW SHEET OF NEW PLANT OF INTERNATIONAL SMELTING & REFINING COMPANY

The Copper Queen Consolidated Smelter was the subject of a paper by Mr. FOREST RUTHERFORD of Douglas, Arizona. The plant was started in 1904 with five blast furnaces and four converters, and was immediately enlarged to ten blast furnaces and seven stands of converters, being completed in 1907. Although larger, it still contained no reverberatories. The furnace charges were quite fine, 40 per cent passing a ¼-in. screen, and as a consequence dust losses were high. An investigation resulted in correcting the trouble by enlarging the dust chamber, diverting converter gases from the main chamber through a separate flue and header to the stack, and finally, after experiments with the Dwight-Lloyd sinter-roasting process, adding six McDougall roasters and two reverberatories. Changes in ore supply necessitated the later construction of one more reverberatory and three roasters. Again, on account of an increase in sulphide ores, seven more roasters were added to partly roast the material for the blast furnace and give better control over the sulphur content, and consequently the grade of matte. The old barrel-type of converters were replaced with 12-ft. Great Falls vertical type, and acid lining gave way to basic. Where the old plant in 1904 could treat with difficulty 2000 tons per day, the present plant can easily handle from 4000 to 5000 tons and can be run in such a manner that metallurgy and costs can receive careful attention.

The method of fettling the reverberatory furnaces is different to that found in other plants. No barren silicious material is used, as with the basic slag made it is too expensive to keep the furnace properly fettled with this material, and it has a tendency to blanket the charge. At present the front half of the furnace is lined with magnesite brick and is not fettled; in the back half ore is used for protecting the lining, running as high as 35 per cent iron, as low as 25 per cent silica, with sulphur from 15 to 18 per cent, and copper about 5 per cent. It is essential that the ore contain enough sulphur to matte the copper, or it will be carried out in the slag in the form of prill.

Progress in Copper Metallurgy in the Globe District, Arizona, is briefly outlined in a paper by Mr. L. O. HOWARD of the Old Dominion Copper Mining Co. Prior to the present decade different small smelting plants had been operating in the district, and the Warrior Copper Co. had made an unsuccessful attempt to leach oxidized and silicate ores with sulphuric acid. The United Globe and Old Dominion smelters remained in operation, but they were poorly equipped and were operated intermittently on account of uncertain supplies of ore due to poor railroad facilities. With improved transportation facilities conditions improved; but it was not until Phelps Dodge & Co. obtained control of the Old Dominion that a betterment in metallurgical practice began. The furnace equipment has been increased until the plant has a capacity of 1500 tons of charge daily. No reverberatories have ever been built, and the fine concentrates are mixed with coarse ores, relying on adequate dust chambers to recover the flue dust. Improvement in converting practice began when the usual barren silica and clay lining was replaced by silicious copper ores with aluminium slime from the concentrator for a binding. Later, blast-furnace flue dust was added to the mixture to the extent of 25 per cent without materially shortening the life of a lining. Finally, the Great Falls type of basic-lined converter was adopted. With this installation, using only one shell at a time, it has been possible to produce more than three and one-quarter million pounds of copper per month from a 42 per cent matte. One converter has been in continuous use for over 18 months, producing more than 45,000,000 pounds of copper without expending one cent for repairs to the lining.

The existing concentrator was remodeled in 1912, its capacity being increased by 500 tons. Oil flotation is used for the recovery of the fine material.

The Design of Modern Copper Plants is ably reviewed in a paper by CHARLES H. REPATH of Los Angeles, Cal., who has constructed some of the most modern copper smelters. The author speaks of the necessity of an organization of experts in order to secure the best results in design and construction of a copper smelter. The Washoe smelter of the Anaconda Copper Mining Co. is cited as the first of the great modern plants that was built by a corps of trained specialists. The design was based on experimental work in older plants; but as larger units were required new designs were made either by the company's engineers or by manufacturers, with the result that many innovations were made, such as large roasting and reverberatory furnaces, blast furnaces and converters. The segregation of the different departments was adopted because of the magnitude of the operation and to provide room for extension.

The author reviews the general principles in design and construction that are now followed in copper smelting plants. An accurate sampling and weighing plant is a necessity if metallurgical operations are to be conducted intelligently. The modern sampler delivers 1.6 lb. of ore to the sample bin for every ton that passes through the equipment. Automatic-recording belt-weighers record the weight to within 0.5 per cent. Belt conveyors are used for transportation of ore between different departments, displacing intermittent methods by means of cars. Bedding plants are used to secure proper mixture of ores for the furnaces. The weight and analysis of the bedded materials are known, and when the bed is partly completed calculations are made to determine its constituents and see what additions must be made to give the desired mixture. The beds are uniformly built by automatic trippers and reclaiming is done by Robins-Messiter machines, which remove the material simultaneously from all parts of a cross section of the bed and deliver it to conveyors.

In the design of roasting furnaces concrete hearths are proving satisfactory and are likely to displace the ordinary brick hearth. The furnaces are of the McDougall type, with superimposed hearths, large central shaft, and air-cooled rabbles and arms. In the Herreshoff furnaces installed at the Calumet & Arizona and the Arizona Copper Co., air is delivered to the furnaces under pressure, and is positively circulated through the vertical shaft and rabble arms.

For the recovery of flue dust, the author is of the opinion that combinations of the flue system, with baffle plates, partitions or wires, and the Cottrell electric precipitation system, may be adopted. Chimneys are built of reinforced concrete, common brick, special brick, and steel plate lined with brick or unlined, depending on conditions. The United Verde has a steel chimney with a 4-in. lining of brick, 30 ft. inside diameter and 400 ft. high. Smoke damage is a problem receiving a great deal of attention, and is being solved by building acid plants or by using high chimneys to diffuse the gases over as wide an area as possible.

Improvements in reverberatory construction have been in the length and width of the furnaces, the use of a larger brick and heavier roofs, the application of fettling material at the sides of the furnace, and the utilization of waste heat for steam generation. Fuel oil and pulverized coal have supplanted direct coal firing. Large furnaces 175 ft. long are being designed, using pulverized coal for firing, and charging the ore along the sides of the furnace. There will be a continuous flow of slag as in blast-furnace practice.

Blast furnaces have been increased both in length and width. They have been built up to 87 ft. long and 7 ft. wide, but the trend of furnace building indicates a length of about 40 ft. and a width of 4 ft. Such a furnace will treat over 1000 tons of charge in 24 hours. Jackets are being made in one length instead of two. 17 ft. long and 3 ft. 4 in. wide. Furnaces are being built with air-cooled tops of structural and plate steel and no brick work. The use of hot blast has not proved satisfactory, although in theory it should be economical; but the first cost of the furnace is greater and the repairs may be more due to greater complication. Mechanical systems are used for delivering ores to the blast furnaces. Charges are usually made up at storage bins, weighed into scale hoppers and dumped into charge cars. The latter are then hauled to the furnaces by electric motors and dumped by air hoists.

"At the Calumet and Arizona plant the method of charging the furnace is new and unique. The ore and coke bins are located on the charging floor, and above it, so that the material will drop through openings in the bottom of the bins into the charge cars. These bins are filled by means of conveyors from the bedding system where the ores have been properly mixed ready for charging the furnaces.

"The gates in the bottom of these bins are air operated, and so are easily manipulated. The large charge cars stand on scales located in the floor, and the man who has the work in charge loads into them the ore or the coke, as may be required. These cars have four compartments, so that the amount placed into each compartment will be the amount required in the section of the furnace that it is supposed to serve. After the car has been loaded, it is moved forward and dumped into the furnace. The bottom of the car is on a 45 deg. slope, so that as soon as the doors are released by the operator, the charge drops into the furnace. There are four cars to each 40-ft. furnace and they are alternately loaded with ore and coke. The car is electrically propelled. There are four large doors to each furnace and they are operated by compressed air.

"Another unique feature in the construction of these furnaces is the method of supporting the side and end jackets. The side of the furnace is supported by a built-up plate girder which becomes the lower side of the bustle or main air-pipe, thus using a minimum of space for supporting the jackets and permitting their removel when necessary for repairs. From this heavy girder, and also from the girders at the top of the furnaces, screw jacks are provided, and they are connected to the top and center of the jackets, the screw adjustment permitting the securing of the jackets in a strong and substantial manner."

Slag disposal is accomplished by hauling to the dump in ladle cars holding from 20 to 25 tons. Under certain appropriate conditions the slag can be granulated in water and sluiced to a dump. The recovery of the heat in the slag has been the subject of much experiment, but little has been accomplished in a commercial way.

Large cylindrical and vertical converters with linings of magnesite brick are now generally used. Cylindrical converters are built up to 10 ft. in diameter and 25 to 30 ft. long. The vertical type is built as large as 20 ft. diameter. The method recently adopted for disposing of converter slag is to carry it by cranes to reverberatories into which it is dumped. The furnaces act as settlers which permit the matte to separate from the slag. Where converter slag is to be used in the blast furnace it is cast into a mold arranged on a machine such as a Walker casting machine. The breaking of ladle skulls is now done by the McGregor skull breaker in which a drop hammer on a traveling crane breaks the skulls into pieces small enough to pass a grizzly with 6-in. or 8-in. openings. Copper is handled in casting machines of two types, round and straight-line. While

more power is used about a modern smelter, it is produced cheaper than formerly. Costs have been greatly reduced in every department of a modern copper smelter.

The Physical Properties of Copper was the subject of a paper by Prof. CARLE R. HAYWARD of the Massachusetts Institute of Technology. The paper gives electric and thermal conductivities and an account of the effect of gaseous and metallic impurities. Accurate equilibrium diagrams are a great aid in choosing elements to produce a certain effect. The heat treatment of copper alloys is of greatest importance and needs systematic research.

Mr. Addicks discussed the effect of oxygen on copper and suggested the casting of ingots on end as in steel practice.

Electrolytic Copper Refining was the subject of two papers on this subject, covering the development and progress in the art of electrolytic refining.

The first, by Mr. A. C. CLARK of the Raritan Copper Co., Perth Amboy, N. J., states that commercial electrolytic refining of copper did not begin until 1860, when batteries were used as a source of current. The dynamo came into existence in 1866. The Welsh process of copper refining had been developed to a high state of

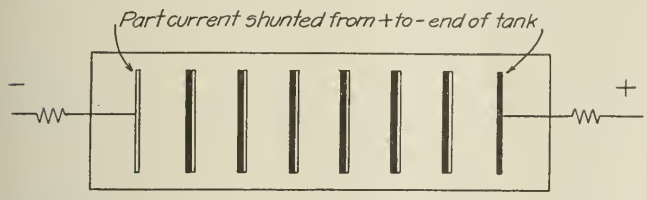


FIG. 2—SERIES SYSTEM

perfection, but failed to produce copper of high electrical conductivity. Gold and silver could not be parted from copper by this method, and in 1883 electrolytic copper refining began to be widely considered. Two refineries were established in 1887, and from that time the growth in electrolytic refining was enormous. The present output is about 1,500,000,000 lb. per annum.

Two systems of electrolytic refining are in use, the series and the multiple, each having advantages and disadvantages. The arrangement in the two systems is shown in Figs. 2 and 3.

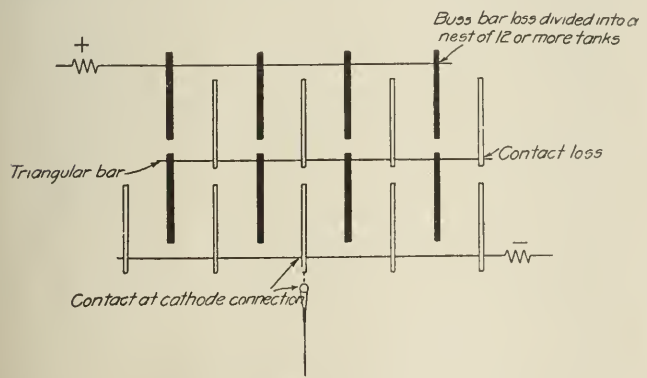


FIG. 3—WALKER MULTIPLE SYSTEM

The series system probably found favor in early days owing to lack of a suitable generator. Standard generators having a normal ampere output were satisfactory for use in this system, while it was necessary to use a number of generators connected in parallel to generate sufficient ampere current for the multiple system.

The multiple system has been greatly improved in recent years, and the former difficulties simplified by Walker's arrangement. Instead of using one tank subdivided into two cells, with heavy copper bus-bars on each side of tank and individual connecting contact strips between the electrodes of each cell, Mr. Walker groups his cells in batteries of from 10 to 17, requiring only one heavy bus-bar for the first and last cells, and by using small triangular copper bars on the intervening partitions of cells, he effects a two-fold saving in voltage, due to a shorter electrical circuit and to a lower resistance due to the sharp contact between the anodes and cathode rods and the triangular bars. This system also largely decreases the cost of installation. The internal electric circuits—namely the rod supporting the cathode and the clips between the cathode and cathode rod, the copper resistance of the anode itself, and the three electrode contacts—still form a serious loss in the multiple system that is not in evidence at all in the series system. However, the potential of the multiple system is so extremely low that it is easy to obtain an ampere efficiency of 90 per cent, while with the series system the current leaking from the first positive to the last negative electrode in the tank effects a power loss which fully equals the loss by the voltage drop in the copper circuit and contact resistance of the multiple system.

The quality of electrolytic copper has greatly improved. Early production was irregular in quality, due to impurities, and sold at a discount from the price of Lake copper; and this unjust discrimination has continued to the present day. At present electrolytic copper is uniform in quality and far superior, by analysis, to Lake copper. The early irregularities in quality were due to engine or generator troubles, insufficient circulation of electrolyte, undue variations in temperature, irregular chemical composition of solutions, etc. At present, however, electrolytic cathodes are hard and smooth and assay 99.96 per cent copper. As showing the high degree of purity of electrolytic copper now produced, its conductivity is frequently 102 per cent and over, based on Matthiesen's standard on supposedly pure copper in 1865. Arsenic is the most deleterious substance in refined copper. If 0.01 per cent is present, the conductivity is reduced about 3 per cent. The maximum quantity of arsenic permissible in first-class electrolytic castings is 0.002 per cent in oxide form.

Electrolytic solutions are generally circulated by centrifugal pumps invented by F. L. Antisell, of Perth Amboy. The pump is made of hard lead, without packing glands or wearing parts being subjected to corrosion. Charging machines are used to charge the furnaces, which have capacities up to 500,000 lb. Furnaces are partly or wholly lined with magnesite or chrome brick instead of the old silica brick, thus effecting a saving in slag production and cost of repairs. Casting machines are generally used. In the Clark & Clark casting wheel used at the Raritan works, the copper is tapped from the furnace into a ladle and six bars poured simultaneously, the molds being set radially on the casting wheel.

In the paper by LAWRENCE ADDICKS, the author points out that the development of the dynamo provided a suitable source of current for electrolytic refining and at the same time made possible the development of many electrical industries and thereby created a demand for high conductivity copper which can be produced only electrolytically.

If we say that electrolytic refining costs ½c a pound over fire refining and that copper sells for 15c a pound, it will take but a 3 1/3 per cent gain in conductivity to pay for the refining, when electrical uses are involved. Further, it is quite impossible to make a clean separation of silver and gold from copper by fire methods, while the "values" in cathode copper run but a few cents a ton. Copper is nearly always associated with silver and gold and our ½c a pound increase in cost calls for but $10 a ton of either or both of these metals to justify electrolysis from this standpoint.

The author divides the development of copper refining into three stages: That of early development; that of tonnage extension, and that of efficiency work. The first period ends with the introduction of mechanical ladling and the general use of cranes for handling electrodes; the second period covers about six years and witnessed the construction of the first really large plants; the third period covers the ten years just closed, with plenty of work in sight to put refining on a finished basis.

As a result of the construction of large furnaces, up to 600,000 lb. capacity, refining is done for less than half the cost in the best of the old hand-ladled furnaces.

Furnace charging is now done mechanically at the rate of 300,000 lb. an hour. Melting has been accelerated by forced and induced draft, and the modern furnace has waste-heat boilers. Hand-firing, combined with what is practically a gas-producer fire-box, holds its own as against mechanical stoking, oil firing or the use of pulverized coal. Coal consumption has decreased with the increase in size of furnaces, from about 20 per cent at 40,000 lb. to 10 per cent at 600,000 lb. Hand-rabbling has been displaced by blowing with compressed air. Skimming is done by rabbles, but the proportion of slag made has been reduced from 4 per cent to less than 1 per cent by keeping silica from the furnace lining, or from coal ashes, away from the cuprous oxide formed while melting and blowing. Crushed low-sulphur coke or anthracite coal is used to blanket the bath instead of charcoal. Poling is still done with green hard-wood poles. Ladling is done mechanically at as high a rate as 90,000 lb. an hour. Fettling is practically eliminated in basic-lined furnaces.

The only obstacle remaining to making furnace refining a continuous melting process, is sulphur brought over as sulphates from the tank-house or absorbed from the products of combustion.

The characteristics of the power requirements are high amperage, low voltage direct current, with a 100 per cent load factor. As individual circuits are limited to about 1500 kw., the reciprocating steam engine is at its best under these conditions, and up to date a high-economy, slow-speed, compound- or triple-expansion engine, generating a kilowatt-hour for about 15 lb. of steam at 150 lb. pressure sq. in., 100 deg. Fahr. superheat, and 27-in. vacuum, has been favored.

In the tank-house the Walker system of connections mentioned above has been adopted. The size of anodes has been increased to 3 ft. square, and even to 4 ft. in one leaching plant. The number of anodes in a tank also has been increased from 26 to 32. Current densities have risen to nearly 20 amperes per sq. ft. A current efficiency of about 90 per cent seems to express the economical balance between labor and power. Lead-lined wooden tanks are still used, but much experimenting is under way with various types of tank construction. With anode copper of 99 per cent or over, an electrolyte with 2.5 to 3.0 per cent copper and 12 per cent free sulphuric acid will give good results with almost any quantity of arsenic, nickel, etc. The electrolyte is generally purified by daily diverting the necessary portion and removing copper and arsenic as a cathode sludge, using insoluble anodes. The resulting liquor is concentrated by steam in lead-lined tanks and direct heat in iron vessels to a heavy liquor consisting of strong sulphuric acid and sodium sulphate, the sulphates of iron, nickel, etc., having fallen out as anhydrous salts. The sodium sulphate can be removed by chilling, and the sulphuric acid returned to the electrolyte. The addition of a small quantity of hydrochloric acid or salt causes antimony to slime as oxychloride. Glue or similar organic addition agents in small quantities aid in forming smooth cathodes.

The refining of anode slime is still in a transitional stage. Wet processes are being experimented with on account of metal losses in fire processes. A simple fusion of raw slime will give bullion, matte and slag. The bullion will contain lead, copper and the precious metals; the matte, copper, silver, selenium and tellurium; the slag, arsenic, antimony and the more easily oxidized metals. If the slime is roasted to oxidize copper, and that metal then dissolved as sulphate in suitable tanks, the remaining slime will form little matte when fused. After fusion in a small basic reverberatory the bath is skimmed clean and the base bullion refined to a high grade, done by blowing and nitreing. The slag is sorted, part sent back to the anode furnaces, part desilverized by a quiet fusion to free it from prills and part charged back into the silver furnace. The silver and gold are generally parted electrolytically and the resulting gold slimes treated for recovery of platinum and palladium. Selenium is recovered from the silver refinery flue dusts by leaching and reduction with sulphur dioxide.

One of the great difficulties in the way of devising a comprehensive wet process lies in the great variation in composition of the slimes at different times and places and in the number of elements present. The strong solvent action of ferric sulphate upon copper and the purity of silver chloride precipitated from foul solutions give a foundation for a wet process. The progress in electrostatic fume recovery is helping out the older process.

Leaching of Copper Ores was the subject of a paper by Mr. W. L. Austin, Riverside, Cal. This is an elaborate compilation, correlating important data collected from the recent extended experiments of different companies. The process is applicable under different conditions as at Chuquicamata, Anaconda and Calumet & Hecla Sulphuric acid is the choice of lixiviants. As to precipitation, local conditions determine the choice between scrap iron or chemical or electrolytic precipitation.

Friday Sessions

The two last sessions of the Section on Metallurgy were held on the morning and afternoon of Friday, Sept. 24. The morning session in which Mr. Chas. Butters presided was devoted to the symposium on gold and silver, arranged and edited by Mr. C. W. Merrill. The papers by G. O. Bradley on a coarse crushing plant of 1000 tons capacity, L. D. Mills, and M. H. Kuryla on crushing and grinding, M. H. Kuryla on solution of gold and silver, L. D. Mills on filtration or separation of metal-bearing solution from slime residue, and G. H. Clevenger on precipitation were read and discussed.

The afternoon session in which Mr. E. B. Braden presided was devoted to the papers on zinc (symposium arranged by Mr. W. R. Ingalls), lead, and fuels.

Limitations of space force us to reserve accounts of all Friday papers and discussions for our next issue.

All the social functions of the Congress and the excursions were carried out according to the program. The whole congress was a great success.

Canada Mineral Production.—The value of the mineral production in all Canada in 1914, according to revised statistics, was $128,556,268, as compared with a total output valued at $145,634,812 in 1913. In the Province of Alberta the 1914 production was $12,684,234 as compared with $15,054,046 in 1913. Coal is the leading product in this province with about ten and a half millions in 1913 and nine and one-third millions in 1914. No gold is recorded as having been produced in 1913 and only to the value of $992 in 1914.

The Aniline Dye Situation*

BY I. F. STONE

In rising to speak of the aniline dye condition in the United States at this time, it is perhaps needless to repeat what is already known to those who are interested in aniline colors either as merchants or consumers, and in fact, known to many of the public through the newspapers; that there is a very great shortage in supplies owing to the fact that goods, which formerly came from Europe upon which we depended largely for our supplies, are by reason of the war no longer sent over; therefore, American consumers are not able to get anything like the supply to which they have been accustomed and upon which they depended.

Eighty per cent of the colors consumed in the United States were brought over from Europe, principally from Germany, so that upon the stoppage of the imports from Europe, 80 per cent of the supply would naturally disappear. The other 20 per cent had been furnished largely by American manufacturers, but even this 20 per cent of the supply has not been maintained by the American manufacturers because they have been depending upon Europe for a large part of their intermediate or raw products, and when they were no longer able to get these products from Europe, naturally they could only run their factories as long as their stock on hand would enable them to do so. Their only chance, then, to continue running their factories was to make these raw or intermediate products themselves, and while this has been done to some extent, as I will explain later, it has not yet reached a stage where they can get full supplies of every raw material they need to produce the full line of colors which they have been manufacturing. Consequently they are unable to furnish some of the colors which they formerly supplied.

This leaves the consumer in a very critical position, as if he wishes to run his factory he must do so without his usual colors, meaning that he would have to make a different class of goods as far as colors are concerned, or else only operate part time, or close down altogether for lack of these dyes. Most of the factories have adopted the part-time method, in that they are manufacturing such goods as require little or no dyestuff, or else manufacturing such goods for which they can secure colors in America to manufacture. In some lines, for instance the hosiery and possibly the leather manufactures, this can be done to quite a large extent, as they use mostly blacks and other dark colors which are manufactured comparatively largely here; that is, for hosiery, direct and sulphur blacks, and for leather, blacks, nigrosines and logwoods, which can be obtained here almost in the necessary quantities. Other lines of manufacture, however, requiring fancy shades—such as silk manufacture, or manufacture of goods requiring indigo, alizarines, and other fast colors, paint and printing ink manufacturers, requiring special colors for their lakes to make their paints and printing inks, paper manufacturers requiring large quantities of blue to manufacture white paper and fancy shades, and many other industries not mentioned—are unable to obtain anything like their requirements and are accordingly not doing their usual volume of business, and many employees are therefore working only part time at a consequent great loss to themselves and to their employers.

The reason for this acute situation is manifestly, of course, the present European war, but, as a matter of fact, it could have been avoided largely by what I might call better judgment of two nations, viz., Germany and the United States. In explaining the situation I shall perhaps have to say something which will reflect upon the business methods of one nation—the German—and the political methods of the other nation—the United States. But whatever I do say will be without animosity, and simply a plain statement of facts, and should be taken as such.

*An address delivered before the National Exposition of Chemical Industries, New Grand Central Palace, New York City, Sept. 22, 1915.

The Attitude of the German Color Manufacturers

At the beginning of the war it was, of course, impossible for the German factories to ship their usual quantities over here because of the fact that the German Government had taken charge of all the railroads and other means of transportation for moving their troops and war supplies, and the German factories could not therefore get their colors to seaport for shipment; but after a couple of months this condition changed so that they were able to get their goods to the seaport, and did commence to make quite good size shipments to the United States, owing to the fact that they were able to do so on neutral or American vessels, and there was then no interference with these shipments on the part of England. The first large shipment, for instance, was made on the SS. Matanzas, which was chartered by American firms and sent over specially for the bringing over of dyestuffs, and this vessel subsequently made several other trips.

After this followed many other chartered vessels, and comparatively regular shipments were made until the spring of this year, when they ceased completely, for the reason, I believe, partly of the action of England in taking measures to prevent such shipments, and partly because the Germans were disinclined to make shipment when they could not get anything in return from this country, cotton and foodstuffs for instance. Had, however, the German firms taken advantage of the time when they could make shipments and had sent to this country a large supply of their products, their agents here could have accumulated large stocks which would have carried them over a long time and so largely prevented the acute shortage of the present time. But for reasons best known to themselves, they decided to ship to this country each month only about 75 per cent of their regular normal shipments, consequently a shortage of at least 25 per cent, and perhaps more, continued in spite of the German shipments. When I say that the German factories could have made large shipments, I say this for the reason that normally only about 20 per cent of their production was shipped to the United States, while the other 80 per cent was used in their own country and shipped to other parts of the world, and as at the time of the war they were barred from shipping to other parts of the world, a large percentage of this 80 per cent was available for shipment to the United States, and they could therefore have shipped to us many times the quantity they did ship, and if they had done so their American agents might have acquired a stock which would take care of their customers for perhaps a couple of years or more on some, if not all, of the colors. I say, therefore, that the German firms are responsible for the difficulty and the acute position of the American consumers. Their primary reason for this holding back of shipments was probably due to the fact that they did not want American consumers to get an oversupply of colors so that they could make up extra quantities of goods which they might use for export to customers in other countries who had formerly bought the same goods from Germany, but who could no longer obtain them. Therefore, they restricted as far as they could the American supply so that they would only have enough goods to supply what might be called their normal trade and could not increase their production.

On the intermediate or raw products which they had formerly shipped to American color factories an embargo was immediately placed by the German Government, so that they could no longer be shipped, the embargo being apparently for the reason that many of these materials were for the use of manufacturing explosives which were required by the German Government in their war movements; but as a matter of fact many of them, like aniline oil, beta naphthol, paranitraniline, naphthalene, and such articles, were not so necessary for this purpose, and large quantities of these could easily have been shipped over here and used in the manufacture of colors by American factories, and also in many cases by consumers themselves, as, for instance, aniline oil for blacks, and paranitranilin and beta naphthol for manufacture of colors by paint manufacturers.

The movement of German colors and intermediate products and chemicals was really controlled by a committee called "Verein zur Wahrung der Interessen der Deutschen Chemischen Industrie," the chairman of which, I understand, was a director of one of the large German color factories, and the reason then that larger quantities of various products were not sent when they could have been sent was evidently due to the judgment of this committee in reducing and finally stopping, because they considered it to the best interests of their manufactures to do so, for reasons already partially explained, and they therefore are really responsible for the present acute condition of the aniline dye supply in this country.

Whether or not it was really to their advantage to take this position it certainly was not to the advantage of American consumers, therefore in the future it seems to me they should bear in mind the position taken by German manufacturers in that the American consumers' position was not considered, and in the future ally themselves as far as they can with American manufacturers who are developing or about to develop the manufacture of aniline dyes in America to as large extent as may be possible, or to a comparatively small extent if the American Government does not come to their support by fixing a new and higher tariff on these goods so that American manufacturers can compete with Europe under normal conditions, but to a large extent if such protection is given.

The Situation of the American Manufacturer and the Necessity of a Tariff

This is really the crux of the whole situation as far as American manufacturers are concerned, viz., whether or not they will be given proper protection, and if so, as I have said, the business will develop to a large extent and in the course of time be practically independent of foreign supplies. I made this same statement in a circular which our company issued on Sept. 1, 1914, just a month after the war started, that is, that the American manufacturers could not make much progress without such protection, which I again repeated in an address before the American Chemical Society of New York on Oct. 9, 1914. As a result of this address, a committee was appointed by the American Chemical Society to look into the matter, and this committee subsequently reported on Nov. 6, 1914, that such protection was necessary, and advocated that the present duty of 3 per cent ad valorem be continued with an additional duty of 7½ cents per pound specific on finished colors, and an ad valorem duty of 15 per cent and 3¾ cents per pound specific on the intermediate or what might be called half-finished products.

This necessity was so apparent that it was even signed by one of the committee, Mr. H. A. Metz, who is the American representative of a large German color factory, whose personal interests naturally lie in the importation of colors, and who would not have signed it had it not been absolutely a necessary action if the development of the color business were to be largely increased in the United States.

This resolution, or report, was duly sent to the proper authorities in Washington, and has been on file there since that time. It is a reflection, I think, on the American Government that no action whatever has been taken in this matter, but here comes a question of politics, the present administration having been elected on the platform advocating reduced tariffs, and therefore will not apparently go back on their platform, even under the present unusual and unexpected conditions, even though American consumers are suffering for relief, in that many thousand employees of manufacturers requiring colors are reduced to only part time and, in fact, some of them laid off entirely by reason of their employers not being able to secure the necessary amount of dyestuffs to continue their regular productions.

In other words, the position of American consumers at present is not a political one, but one of cold fact, and should in my opinion have the attention of the administration irrespective of previous policies. Except that they have had practical example of the workings of a low tariff on aniline colors and coal tar products, and its flat failure as connected with this line of business, the result of which is the present deplorable condition, the present administration is no different from previous administrations for the last twenty-five or thirty years, both Republican and Democratic, none of them having given this necessary protection, and as a result not allowing the business to develop as it would have developed had they done so.

It is perhaps some excuse that they did not realize how large a part in the success of the manufactures of textiles, leather, paints, and many other lines, depended on their supply of dyestuffs, in that the business itself was perhaps not large enough to demand their careful attention, and they did not take into consideration the fact that so many other great lines depended on their supply of these goods. This fact was also not realized by many of the American consumers themselves, as is evidenced by the fact that during the many years that the tariff matters were before successive administrations many American consumers of dyestuffs fought an increase of duty thinking that it might increase their costs and evidently preferring to buy foreign goods at what they considered lower prices than to support the manufacture in America at a possible increase in cost to themselves by reason of a higher protection.

The fallacy of this position is now absolutely apparent in that the consumers are now not only not able to get sufficient supplies for their wants, but on what they do get are forced to pay fabulous prices, and certainly the extra cost of their supplies and their losses through failure to run their factories regularly will far exceed a slight possible advance in the cost of dyestuffs by reason of their being made in America under a protective tariff.

As an instance of prices which they are forced to pay when they do get goods I might mention a few products:

Sulphur black, which is used very largely by the hosiery and cotton trades, and which sells normally at about 20 cents per pound, has brought as high as $2.75 and even $3 per pound.

Indigo, which sold formerly at about 15 cents, has been sold as high as $1 per pound, even more.

Aniline oil, the normal price of which is about 10 cents, as high as $1.75 per pound.

Beta naphthol, with a normal price about 12 cents, sells as high as $1.50.

Paranitraniline, normally about 15 cents, sells as high as $1.75.

I might continue this list indefinitely, showing where all products for which consumers depended on European supply, that is, which were not manufactured here, are now selling at anywhere from five to twenty times their normal value.

I might call attention in this connection to the fact that these enormous advances do not apply on colors and products which were made regularly in America; for instance, such products as direct black, Bismarck brown, chrysoidine, nigrosine and any number of other colors, have not been advanced by American manufacturers more than two or three times their normal selling price, and this advance was only caused by reason of the fact that their raw materials are also used in the manufacture of ammunition and explosives and are now in large demand for this purpose, so large a demand, in fact, that American manufacturers of colors have been unable to get adequate supplies, and so for what they do get pay abnormal prices; benzol, for instance, having advanced from a normal price of about 20 cents to as high as $1.25 for immediate shipment, and on contract to about 65 cents at the present time, while toluol, with a normal price of about 25 cents, has been sold as high as $6 for immediate supply and on contract at this time about $4.25. Had these advances not taken place by reason of their demand for other purposes the manufacture of American colors could have continued on almost normal lines, so they are not to blame for the necessity for advancing prices to the extent they have, which, however, is no comparison to the advance in the prices of European colors which have not been made here.

I might say that the one American manufacturer of aniline oil before the war, even in the face of these enormous advances, continued to fill contracts at the old contract prices, and when they arranged to increase their production to a large extent only advanced the price in proportion to the advance in raw materials, and had it only been able to manufacture enough aniline oil to supply the country, which it was not at the time, the price on this article would not have soared to $1.75 as it has, but would have been held to some reasonable figures. This shows the policy of real American manufacturers, which is to protect their customers as far as possible under unusual conditions, and has also been the policy of color manufacturers.

The matter of tariff being so important a factor in the development of the color business in the United States, I might call your attention to an article recently written by Dr. B. C. Hesse, a well-known aniline expert, and published in pamphlet form, headed, "Who Killed Cock Robin?" and which gives the United States tariff history for the past thirty years. He calls attention to the fact that there was from 1880 to 1883 a duty of 35 per cent ad valorem and 50 cents per pound specific on aniline colors, which gave ample protection to the industry, and as a consequence there were then nine or ten factories in the United States, and the prospect of becoming independent of other nations for our supply of these aniline products was bright indeed. But the passage of the tariff act of July 1, 1883, which abolished the specific duty of 50 cents per pound, leaving only the ad valorem duty of 35 cents, and fixing a 20-cent duty on the intermediate products, which left only a net protection of 15 per cent, immediately checked the industry here. No new factories were started, and within one year after the new tariff took effect five of those already established were forced to succumb and go out of business, leaving only four to continue the work, who have since stayed in business but have not been able to develop to any extent. I might say that a specific duty of 50 cents at that time was not exorbitant, as the prices of aniline colors then manufactured were very much more than they are to-day, colors, for instance, selling at $4 to $5 per pound now sell at only 50 to 60 cents per pound, so that the 7½ cents specific duty now recommended by the American Chemical Society would not be very far out of proportion to the 50 cents per pound at that time.

Had a proper duty been kept on these aniline products, say from 1883 to about 1900, during what might be called the golden progress of the industry, when so many new colors and products were brought out, the business might be here to-day in the same prosperous condition as it has been in Germany, where, as everybody knows, enormous factories have been erected and the business of the world practically controlled by them. It is, of course, due to the Germans to say that many of their new products were patented colors produced through the careful research work of their chemists, but no one can say that American chemists would not have been equally diligent in research work had they had the same opportunities. Moreover, had the United States at that time had a proper patent law which would compel the manufacture in this country of all goods patented by foreign residents, it would have protected the industry and insured its great success. Our legislators, however, did not appreciate the importance of the business, and so failed to give us the proper protection and proper patent laws, and therefore the business has drifted away from the United States and resulted to the great credit and prosperity of the German manufacturers.

However, these patents have now practically expired, and the American manufacturers are free to manufacture practically everything that is needed, so I must emphasize again that it is now only an insufficient tariff which prevents the development of the American industry in the future. This pamphlet of Dr. Hesse's also shows that in the various tariff negotiations in Washington during the various administrations, fights against an increased tariff were made not only by foreign manufacturers and their representatives, but were actually supported by American manufacturers and consumers whose names are given and who are now, I think, very sorry that they took this position and did not rather favor a protection and development of the American industry.

The American Consumer

To show you the lines of manufactures which are dependent on their supply of dyestuffs to continue their regular production, I would say the most important, perhaps, are the textile manufacturers, comprising cotton, wool, carpets, knit goods, silk, cordage, shoddy, dyeing and finishing. The following figures are taken from the census of 1909:

	Establishments	Employees	Capital	Salaries and Wages	Value of Product
Cotton ...	1,324	387,771	$822,237,529	$147,270,903	$628,391,813
Wool	985	175,176	430,578,574	82,523,776	435,978,558
Carpets ..	139	34,706	75,627,010	17,745,092	71,188,152
Knit goods	1,374	136,130	163,641,171	52,431,680	200,143,527
Silk	852	105,238	152,158,002	46,097,364	196,911,667
Cordage ..	164	27,214	76,020,366	10,995,545	61,019,986
Shoddy ..	88	2,320	6,886,825	1,196,376	7,446,364
Dyeing and finishing	426	47,303	114,092,654	26,261,634	83,556,432
	5,352	915,858	$1,841,242,131	$384,522,370	$1,684,636,499

You will see that there are over 5000 of these establishments with over 900,000 employees, with a capital invested of $1,841,242,151, who are paying in wages annually $384,522,370 and the value of whose product is $1,684,636,499.

Then there are the leather manufacturers and tanners, of which there are over 900 establishments, with a capital of $322,726,952, employing over 62,000 people and the value of whose production is $327,874,187.

Then again there are the paper manufacturers, numbering over 750, with over 81,000 employees, with capital invested of over $400,000,000 and the value of whose product is over $260,000,000.

Then there are the paint and color manufacturers, about 900 in number, with a combined capital of about $250,000,000 and employing 30,000 men.

As I said at first, these figures are taken from the census of 1909, and those who are interested in these particular lines tell me that there has been an increase in practically every industry averaging about 25 per cent, so that the figures should be something like 20 per cent more than those given. Add to these lines of business others which are not separated in the census, such as printing and writing ink manufacturers, shoe dressing manufacturers, and a hundred and one other lines which consume dyestuffs, and I think I could safely say there are upward of 2,000,000 people employed in industries which require the use of dyestuffs and who are now affected by the present shortage. Others affected, of course not so directly, are the public generally, who will soon find that they cannot get what they want, and will have to take what they can get, and if some changes do not take place very shortly a totally new scheme in colors will have to be presented to the American public.

The Attitude of the Administration

We have now come to a point where we are under unusual conditions, and the American industry again has a chance to develop, and it would seem a pity if the present administration would not take the opportunity to help manufacturers to do so.

The New York *Sun,* in its edition of Sept. 3, had a good article on the subject, and an editorial calling the attention of the President to the fact that while he might be engrossed in very serious affairs, such as the Mexican situation and the foreign wars, at the same time the new conditions and new complications arising from the present conditions should warrant his attention to see what prompt action and judicious protective legislation in the matter of the dyestuff industry might do for the country, saying further that the dyestuff industry is a single illustration only of the great trade advantages which the situation promises. This article and editorial were repeated and supported by many other American newspapers, and certainly represent a step toward accomplishing a revision of the tariff on aniline products to take advantage of present conditions.

I might at this time call attention to a popular belief which I consider a mistake, that an advance in the tariff on aniline products would necessarily result in advance of prices, but this is open to question, as while it is true that many of the cheaper colors might be advanced to some extent, on the other hand, the higher-priced colors, which have not been made in America and which are controlled by European conventions, would probably be actually reduced in price, so that the general average price on everything would not be possibly much different from what it is to-day under normal conditions. Then, again, there is the question of the so-called "anti-dumping clause," referring to the fact that it has been the habit of European manufacturers to sell in this country colors which were made here at lower prices than they sold them in other countries, so as to prevent their development here, while at the same time they held prices at good figures on colors which are not made here and so averaged up their profits. I am glad to say that some legislation against these proceedings is favorably considered by the present administration, and no doubt some law will be passed which will prohibit this so-called dumping in the future.

In view of the emphasis I have placed on the necessity of tariff legislation, it may interest you to know what I have discovered in my interviews with various administration officials to get their ideas on the subject.

Some months ago, Secretary Lane of the Interior Department called a meeting of the various chemical manufacturers to get their ideas as to the situation and what was to be done about it, and at that meeting what little I said was to the same effect as what I am now saying, viz., the necessity of tariff action. Mr. Lane made the observation that if this were done it would create in this country a great monopoly or trust, and he did not think it would be advisable; but as a matter of fact the lack of this legislation has simply resulted in a great trust or monopoly in Germany, so I could not see where there could be any reason in this point. Such legislation would not necessarily create a monopoly here, as any one would be open to go into the business; the only point being that it would put us on equal terms with foreign competition, and this is the only result desired—not monopoly.

Mr. Lane further said, however, that the matter would probably be put in the hands of the Department of Commerce, which eventually did take place. Some time afterward I called on Secretary Redfield of the Department of Commerce and found that he was very sanguine of the ability of American manufacturers, through their ingenuity and ability, to create this business without help of a tariff, and instanced a number of new concerns who had started in the business since the war commenced, giving me the names of parties in Elizabeth, N. J.; Chester, Conn.; Edison of West Orange, N. J.; Wappingers Fall, N. Y.; Newark, N. J.; Stamford, Conn.; Perth Amboy, N. J., and Lincoln, N. J., who were about to enter the business, but as I knew most of these parties through previous inquiry I told him they were not being established for the manufacture of colors, but simply for such intermediate products as aniline oil, carbolic acid, beta naphthol and paranitraniline, which are more easily manufactured, and while they might be profitable under war conditions, could not possibly exist under normal conditions, which I believe is true.

Mr. Redfield was very much interested in the matter, and said that his department was doing everything possible to foster the development of the business in the United States, but could not say that he was in favor of higher tariff, as it was against his policy and against the policy of the present administration, but that he was in favor of some anti-dumping legislation which would prevent the selling in this country of European colors at lower prices than to other countries, and he thought something would be done in this line to prevent it in the future.

Nothwithstanding the fact, however, that the administration as represented by Secretaries Lane and Redfield is apparently opposed to higher tariff, it is a fact that in the meantime Dr. Thomas H. Norton, special representative of the Department of Commerce, gave his views on a dyestuff tariff in the New York *Sun* and the New York *Herald* of Sept. 15. He admitted that in spite of the fact that he does not think the general line of colors need any more protection he does feel that some of them, like indigo, alizarine and others, which are on the free list should have some protection to be successfully made here, and if he were to go a little more carefully into the matter he would find that while 30 per cent duty on the ordinary aniline colors might

be sufficient if it were a clear protection, as a matter of fact the intermediate and raw products which are used in this manufacture carry a duty of 10 to 15 per cent, so that the real protection on aniline colors is not half what it apparently is in the bill. If it were possible to buy these raw materials made in the United States at approximately the same prices at which they can be bought in Germany, then the 30 per cent tariff would be more or less effective, but for reasons just mentioned, i.e., the duty on the intermediate products, it is not, and to show that this is a positive fact, without any theories, I would again call attention to the fact that since 1885 there have been practically no new color factories started in the United States, and the great business developed since that time all over the world has been practically controlled by Germany. If these colors had been properly protected, as I have already said, then a large part at least of this great business would have stayed in the United States, and now that we have again a chance to get to a quick development through the present abnormal conditions, certainly we should not throw away another chance to become a great factor in the industry and no longer be dependent upon foreign countries for our supplies.

Manufacturing Costs in Germany and in the United States

In the tariff pamphlet by Dr. Hesse already mentioned, there is a copy of a brief filed with the Congressional Committee who were working on a new tariff in 1908. This brief is dated Nov. 9, 1908, and is a complete statement of the cost and operation of an aniline color plant designated to manufacture 3,000,000 lb. annually. It was written and filed by Mr. J. F. Schoellkopf of the Schoellkopf, Hartford & Hanna Company, now called Schoellkopf Aniline & Chemical Works, and is confirmed and also signed by the Heller & Merz Company, one of the largest and oldest color manufacturers in the United States.

In Table A of this brief it is shown in detail that the cost of such a plant would be $104,000 in the United States and $70,000 in Germany, a difference of $34,000 in favor of Germany.

In Table B the number of employees needed to operate such a plant is given in detail, and shows that their wages would amount to $116,236 in the United States against $61,493 in Germany, again a difference in favor of Germany of $55,000.

In Table C a list of the cost of the material required for running this factory to a 3,000,000-lb. capacity is given, showing that the cost in the United States would be $443,000 for these materials, which are given in detail, while in Germany the same materials would cost only $317,000, a difference of $126,000 in favor of Germany.

In Table D is given the cost of producing the colors as a whole, adding together materials, fuel, labor, interest on investment, depreciation of plant, etc., the table amounting to $693,000 in the United States where it would only cost in Germany $480,000, a difference of $212,000 in favor of Germany.

The net result as shown by these figures is that it actually costs 44 per cent less in Germany to make colors than it does in the United States, and while, of course, these figures are now somewhat old, I think the same difference would still be true at the present time.

Take, however, the possibility that the present manufacturers are not correct in their statements as to this increase of duty being necessary, let us take the opinion of two possible new manufacturers; for instance, Mr. Thomas A. Edison, who when the war started found that he could no longer get the large amount of carbolic acid which he consumed, and which was formerly furnished from Europe, promptly started to manufacture it himself, first making an arrangement with a large steel works for the benzol to make it from. In making the carbolic acid he also decided to produce aniline oil, and has been a producer of these products for some time. It was rumored at that time that he also intended to take up the manufacture of aniline colors, and this same rumor has been repeated in the public press in the last few days. Now, in an interview with him, published in a recent edition of the *Journal of Commerce*, he is quoted as saying that we can only become independent of Germany in the dyestuff industry if Congress will allow a moderate tariff, confirming the opinion of older manufacturers, and showing that after looking into the matter he was convinced that colors or coal tar products could not be manufactured successfully here in competition with Europe unless they had the proper protection.

Then the Pearsite Company of Cannel, Ky., who had lately been extolled by Dr. Norton as having a marvelous new process for manufacturing aniline colors by which they could manufacture them cheaper than the Germans and would soon control the entire consumption of the United States, gave an interview in the New York *Times* of Sept. 9, by Col. H. P. Bope, who is its president and also vice-president of the Carnegie Steel Company. Mr. Bope states in answer to a question as to whether his company could continue to compete with Europeans under normal conditions that he believed that the men in charge of affairs at Washington would readily see the necessity for and would give them the protection in tariffs that comes to all American industries. So you will see that Col. Bope's mind was also running on the line of protection in spite of the fact that the supposed new method of manufacture would entirely alter the whole situation.

The Attitude of the Administration Toward the Present American Manufacturers

Now, to come back to what the Government, through the Department of Commerce, are trying to do to help the production of dyestuffs in the United States, aside from any question of tariff, we find that while they are working diligently to do what they can they are starting from an entirely wrong point of view in that instead of trying to help the present manufacturers in the way of, for instance, securing them very much needed raw material and other helps to their production, they seem to be paying more attention to possible new productions, and to the claims of people who think they have wonderful new methods for producing dyestuffs which will render us independent of Europe for all time.

The first reports sent out by the department were to the effect that many new concerns were entering the field, which I have already mentioned in the account of my interview with Mr. Redfield, but it turned out that these concerns were not intending to make aniline colors, but only intermediate products.

Then the next reports of any interest were to the effect that they were working on agreement with the Swiss manufacturers whereby we were to send over to their country raw materials and the Swiss manufacturers were to make them up into colors and return them to us. That this arrangement has failed of any result is very natural, because the United States did not have the raw material to send—in fact, its own manufacturers could not get enough for their own wants—and if there had been any raw materials available it would have been much better for us to have given them to American factories instead of sending them to Switzer-

land. My own firm has recently had correspondence with Swiss manufacturers relative to furnishing them such articles as benzol, aniline oil, acetate of lime and oleum (which is a concentrated sulphuric acid). They stated they were unable to obtain supplies abroad, and we were obliged to write them that we could not get supplies ourselves, therefore could not send them anything from here. Aniline oil and oleum are out of the question, owing to the immense demand for them from American consumers, and benzol is practically barred because of its extremely high price and the enormous transportation charges for carrying it to Switzerland, which brought the total up to more than they are willing to pay.

The next what we might call important or interesting news given out by the Department of Commerce was an announcement in the New York *Times* of Sept. 4, in which it was stated in an interview with Dr. Norton, that an American had solved our dye problem, in that he had invented a new process for manufacturing colors which was much cheaper than the old process, and which would allow his factory to revolutionize the business in the way of costs and production, and that production would begin within two weeks, with a possible production of 5 tons per day, or 35,000,000 lb. per year —the total consumption of the United States, by the way, being about 30,000,000. The name of the concern which was to make these new colors was not given, but the next day, in the *Times* edition of Sept. 5, it was stated that the firm which would manufacture colors by the new process was the Pearsite company, which had large works at Cannel, Ky., and again repeated, with Dr. Norton's approval, that it would be ready to produce dyes in a few weeks, again mentioning 5 tons daily as its probable production, and further interviews with Dr. Norton on the subject were continued for several days, all to the effect that these new colors would be in the market in a few weeks in the quantities mentioned and would revolutionize the dyestuff conditions of the United States and relieve consumers from the present shortage.

I immediately received letters from all parts of the United States asking if we knew anything about the process and if it were true that colors could be had from this new company in so short a time, to which I replied that I did not know anything about it, except the newspaper reports, but that I doubted if it were possible for such a marvelous change to take place so quickly. Later, however, I have been in communication with parties who have actually had dyed samples and tried out the new colors, but instead of having an unlimited line of complicated colors such as are required by the United States consumers, some 900 in all, and which would be needed, a good many of them, to relieve the present shortage, the new company really only had five colors to begin with. This was also confirmed by an article in the New York *Times* of Sept. 15, stating that this would be the number of colors to be produced and giving the names of the new selling agents for these colors. The point to this matter is simply that instead of a marvelous new discovery which would alter the present conditions and relieve the present shortage of colors, as announced by the Department of Commerce through Dr. Norton, we simply have an experimental proposition which will not relieve the situation to any particular extent.

I do not question but that this Pearsite company may have some method of making colors which will produce colors, but I do say that it is impossible for them to have a method which would enable them to make all of the complicated colors consumed in this country and which are made not only from their base—benzol—but many other raw materials which are combined with coal tar products, but which are not related to them at all, and which they could not possibly manufatcure from a coal tar process alone. I do not believe that the Department of Commerce should allow such exaggerated statements to appear in the public press through their intervention, as it simply results in great disappointment to American consumers, who were hopeful that something had been found at last to supply their wants.

Mr. Redfield now says in an article in the New York *Sun* of Sept. 16 that "home dyes will be plenty soon," which if one did not know the conditions would again build up the hopes of consumers, while unfortunately there is no immediate relief in sight, and it must be months before a full quantity of dyestuffs can be obtained, even after the war is over. American consumers must understand this and take it into their calculations in figuring on their future production, and such statements should not be sent out by the Department of Commerce.

What American Manufacturers Have Already Done

Up to the present time I have mentioned the cause of the present shortage, the reason for and hope for a development in the manufacture of colors in America through tariff corrections on the part of the Government, and the attempt on the part of the Department of Commerce to create a new supply through other than ordinary methods, which, however, up to date has failed to produce anything of importance. I will now tell you what actually has been accomplished by American manufacturers to increase the production of American products in the United States, and those who have aided in this development are firms who will continue in business after the war is over, no matter what the conditions may be, even though they may have to do so at little or no profit unless they have some help from the Government. I am glad to say, however, that the development of the coal tar product business in this country will continue to a large extent, irrespective of what the tariff decision may be, but the development will not be anything as large as it would be if the tariff were corrected.

Aniline Colors.—There were five factories actually engaged in the manufacture of these products before the war, the names and locations being as follows:

Schoellkopf Aniline & Chemical Works, Inc., Buffalo, N. Y. (National Aniline & Chemical Company selling agents).

The Hudson River Aniline Color Works, Albany. (Bayer Company selling agents).

Heller & Merz Company, Newark, N. J.

Central Dyestuff & Chemical Company, Newark, N. J.

W. Beckers Aniline & Chemical Works, Brooklyn, N. Y.

When the war started, and the shortage of foreign goods became apparent, these firms were overwhelmed with orders from American consumers for supplies. For reasons which I have already mentioned, viz., their inability to get raw material from Europe, they were not able in the beginning to increase their production, and were compelled to use only the raw material which they had on hand, and when this was exhausted had to give up some colors entirely. In the meantime, however, some of them have commenced to manufacture these intermediate products, and the rest will undoubtedly do so as quickly as possible. Although I cannot speak specifically for any other factory, I can say that our own factory, Schoellkopf Aniline & Chemical Works of Buffalo, by the first of January will be making largely its own raw material, and this, together with what raw material we can get from other manufacturers, has en-

abled us to insure ourselves of a supply of raw material, so that we have increased our regular aniline products to the extent that by the first of January we will be producing something like 800,000 to 1,000,000 lb. monthly, or, say, 10,000,000 lb. annually, which is about four times our former production. While, as I have just said, I cannot speak specifically for other factories, I have no doubt that they are making equal improvements and will show equal increase in production in the course of time.

It is my opinion that an immediate development in the aniline color business in this country will depend entirely on these five original makers, as they are all equipped with capable and experienced men, who are able to direct much larger production than they are now getting and to manufacture successfully, which is a great advantage they have over new factories which may enter the field, who have not had the experience and necessary scientific help to develop the business quickly; and these factories, while having no connection one with another and no conventions nor understandings of any kind, are a unit in declaring that they must have additional protection in order to develop their business to an extent which would take care of the consumption of the United States.

Other large corporations, like the E. I. Du Pont de Nemours Powder Company, the General Chemical Company and Thomas A. Edison, have been recently mentioned as about to enter the manufacture of aniline colors, but I question if they have any intention of doing so in the immediate future, as their present business is so large and the demands upon them so severe that they will hardly be able to entertain taking up new lines in the near future, another difficulty being the inability of any of us or them to secure at present enough raw materials to manufacture even the amount of colors we could manufacture if raw materials were plentiful For instance, one article, oleum, which is a concentrated sulphuric acid, and which enters largely into the manufacture of colors, is almost unobtainable owing to the enormous increase in its demand, due to present war conditions, which require large quantities of it for explosive purposes, and unless sufficient quantities of it could be secured the development of the manufacture of colors could not be carried on by anybody.

Of course, the present aniline works have arranged for their supply of this product now in advance, so have enough in sight to enlarge their production to the extent which I have mentionel; but for a new concern to start in at this time, I think it would be impossible for them to get this, as well as other raw material, which is absolutely necessary, and for this reason, as I said before, I think it rests with the original five color makers to develop the business for the relief of consumers, and while other concerns like those mentioned may enter the field later, it certainly will not be in time to improve matters much for a year at least.

Two other concerns have been mentioned prominently in the papers of late in connection with the actual manufacture of aniline colors, as distinct from those mentioned as manufacturers of intermediates, both concerns claiming to have new methods which are different from the methods used by the older manufacturers in their production. One of them is the Pearsite company, mentioned above, and the other is the American Cooperative Dyes & Chemical Company, Bangor, Pa., who claim to have a new method for making a hosiery black and some other colors of similar nature, and which is now in the course of formation. These two companies, however, are not known to the trade as manufacturers of colors, and the success of their new methods is, therefore, more or less problematical, and the future only will show whether or not they will be successful in their lines.

Aniline Oil.—Until about three years before the war this very important product for the manufacture of aniline colors, and for producing blacks directly through oxidation in dye houses, was not made in the United States, and was furnished almost exclusively by Germany and England, being in the hands of a convention which controlled the price and conditions. About four years ago the manufacture of this product was commenced on a fairly large scale by the Benzol Products Company, now at Marcus Hook, Pa., whose sales agents are the General Chemical Company, who began with a production of about 1000 tons, the whole annual consumption of the country at that time, by the way, being about 4000 tons. This Benzol Products Company did not make much progress financially, owing to the fact that even when a tariff of 10 per cent was placed on this product the foreign convention immediately reduced their price accordingly, that is, assumed this duty and still sold to their consumers here at the regular prices, and such prices did not leave the Benzol company any profit, for they could not manufacture as cheaply as the Europeans were willing to sell for.

At the beginning of the war, however, the imports from Europe stopped suddenly, and the demand for aniline oil became very acute. The Benzol company immediately took the situation in hand and arranged to increase its production as quickly as possible, and has recently completed a new factory, so that it has increased its production very materially, and eventually will reach about 5000 tons, which will be more than the entire consumption of the country under normal conditions, although the consumption will be increased very largely by the probable development in the manufacture of aniline colors, which is the largest use.

This is the concern I have mentioned as having been so fair in making contracts with its customers, that those who have bought from it have not had to pay the exorbitant prices asked by outsiders, and it is to its great credit, therefore, for working directly for the benefit of American consumers without the possible abnormal profit which it might have secured had it wished to take a different position.

In addition to the Benzol Products Company, there have a number of firms started up since the war to manufacture aniline oil, and some of these new factories have already started to deliver, but even at that the total production is not yet large enough to supply the demand. But the point is that in the end enough aniline oil will be manufactured in America to supply the demands of all consumers, so that if properly protected by tariff it will make this country independent of Europe for its supply of this product.

Benzol.—This is the basis product for the manufacture of aniline colors and products, being used, however, largely for other purposes as well as for explosives. Before the present war the normal production in the United States was about 3,000,000 gal. Since the war, owing to its suddenly increased demand, many steel companies and other similar industries who could recover benzol from their other operations immediately began to do so, so that now it is estimated that the production of benzol for 1916 will be upward of 15,000,000 gal., or about five times the original production. Owing to the enormous demand for it from explosive manufacturers, and for export to other countries, the supply in this country, in spite of the increase, remains insufficient, and very high prices are asked. But the important point is that this large production is now assured, and whenever the foreign demand ceases and the de-

mand for explosives ceases the United States will have ample production of benzol from which to build up her other industries which depend upon it; for instance, the manufacture of aniline colors and other similar products, and inevitably in view of the large supply the prices should not be any higher than those paid by foreign manufacturers for the same product.

Carbolic Acid.—This is an article which has a large consumption in the United States, some 8,000,000 to 10,000,000 lb. per annum, but which before the war was not manufactured here to any extent, because American manufacturers could not compete with the German and English. Since the war, however, many plants have been put in and practically all that is consumed here at present is manufactured in this country. Thomas A. Edison alone, who was an enormous buyer before the war, now manufactures 12,000 lb. daily, according to his interview given in the *Journal of Commerce* of July 30, most of which, however, he requires in his own works, so that he does not have much for resale. Other manufacturers are making it mostly for the making of picric acid for export, but after this demand for picric acid is over then the manufacture of carbolic acid will continue here in large quantities for domestic consumption, and the country should then be independent of Europe for its supply. This is another article which is also used in the manufacture of aniline colors, and will help their development.

Indigo.—There is now being built in Charleston, W. Va., a factory for the ostensible purpose of manufacturing caustic soda and chlorine products. It is, however, being built and controlled by a firm which is the agent for one of the largest indigo manufacturers in Europe, and who, I am informed, have all arrangements made to make indigo if it can be done successfully here, which it can in every way, except possibly not as cheaply as in Europe. With a proper protective tariff, however, this plant could be fully completed for the manufacture of indigo, and surely it would be a great relief to American consumers, who use about $1,250,000 worth annually, to have a plant in this country from which they could draw their supplies and be assured of them in the future.

Intermediate Products.—These products were practically all imported from Europe prior to the war, but since the war factories have been started for their manufacture, so are now produced in this country such articles as beta naphthol, paranitraniline, diphenylamine, dimethyl-aniline, H-acid, benzidine, chlor-benzol, and some others, with more to come, all of which being used particularly by the aniline color manufacturers, although incidentally in some other lines; so again, if these new factories are protected by sufficient tariff, the manufacture will go on successfully and we will again be independent of Europe for our supplies.

Naphthalene.—This is another coal tar product which has increased very largely by reason of the present conditions. Before the war the production in this country was about 2,500,000 lb., while now it has increased to something like 7,000,000, perhaps more, the normal consumption being about 9,000,000 lb., and the difference between what was produced in America and the total obtained from England and Germany, which hereafter they should be practically unable to ship over here by reason of the new large production here, and which should be sold in normal times at as low prices as could be sold by Germany and England. This is also a very important intermediate product for the manufacture of aniline colors, and again a help in this production.

Sulphur Black.—This is a color used largely for hosiery and cotton purposes, and which never before was manufactured successfully in this country, or rather could not be manufactured cheaply enough to compete with European products. The probable consumption of it is 4,000,000 or 5,000,000 lb. annually. Since the war our own concern has taken up the manufacture of this color successfully and is now furnishing the goods to consumers. We are rapidly increasing our production so that we will probably produce 2,000,000 lb. or over in 1916, all of which is practically sold on contract. Two other manufacturers have also taken up its manufacture, and are making contracts over the same period, so that it is probable that in 1916 the total amount of sulphur black manufactured in the United States will equal the former import from Europe, and with a proper protection in the tariff this large volume of business could be retained in the United States against all foreign competition.

What Tariff Protection Would Accomplish

You will see from the above that there is something actually being done in the United States in the development of coal tar and allied products, and no matter what happens in the future a large increase in this production will be assured, but I must repeat once more that if it is to be developed to the extent of supplying the whole amount of dyestuffs needed in the country which have heretofore been imported, it must have help from the Government in the way of an increased tariff, and the help of every consumer should therefore be given to bring about this very desirable result.

I wish to impress upon you in connection with the above list of what has been done, that on many of the products we are already producing in this country the normal consumption of the country, and this production will be kept up if properly protected. A notable exception to this statement, however, is aniline colors, which are so badly needed, but which, owing to their variety and the complicated formulæ and range of raw material necessary to make them, as well as the large amount of capital necessary to manufacture them in a large way, have not been developed to the full quantity needed. But even with these disadvantages, my remarks show that all of the five factories mentioned are making every preparation for development to the best of their ability, and I believe, in spite of the difficulties against them, that by Jan. 1, 1916, when they will all commence to get the benefit of their new installation and increase, they will be producing anywhere from three to four times their former production, which is a very important increase in itself.

I make bold to say further that if these factories were assured of protection they would increase their production still further, and to such an extent that within a year they could furnish the entire amount of colors required by American consumers, and so relieve them once and for all of their dependence upon European manufacturers. When I make this statement I do not mean that they can make every color which has been imported in so short a time, as there are a number of specialties which have some particular advantage in application, fastness, or something of that sort, and require a special raw material, which they would not be able to take up so quickly, and again there are a few colors which are still patented. But what I do mean to say is that they could make the colors necessary to furnish consumers every quantity and every shade which might be required, that is, give them something which they could use in place of the specialties already mentioned, the latter being what we might call luxuries and dispensable until such time as they could again be resurrected or again imported from Europe, as there can be no question but that some colors would probably al-

ways be imported no matter what the American manufacturers are able to do.

Such an assurance of protection would also probably mean the establishment of branch factories in this country of the European factories, as they would not want to lose their business over here, but the establishment over here of such factories would be welcomed by American factories, because they would then have to work under the same conditions that we do, and would not have any advantage in the cost of manufacture. Again, this assurance of protection would probably stimulate the starting of new American companies who would then be willing to advance the capital necessary and take a chance of being successful. So that even if the five original factories mentioned could not live up to the statements I have made as to their ability, they would undoubtedly have lots of new help, and the result would be ultimately the same, viz., the manufacturing in this country of all colors which are needed for its consumption.

The Possibility of Government-Owned Factories

In closing, I might say, however, that there is one thing which might be done in lieu of an increased tariff protection and which has been suggested before in different forms, but which is so reasonable and simple that I do not suppose it will be considered by our political leaders and parties, and that is, the establishment by the United States of a factory or series of factories for the manufacture of the intermediate coal tar products needed by the color manufacturers, and an arrangement to sell same to them at the same prices which are paid by the German manufacturers, even though there might be no profit or even a possible loss to the Government in doing so.

In addition to this great relief to American color makers, the Government, however, would have the greater purpose in mind of having plants already established capable of manufacturing ammunition in case of war, the point being that the raw materials used by color makers are very much the same as those used in the manufacture of various kinds of ammunition and explosives, and certainly such a factory or series of factories would be a very valuable asset for the Government.

I believe it is true that other governments take an interest in and control to some extent their natural resources; for instance, Germany is interested in her potash and coal fields, Japan in her production of camphor and menthol, and other governments in other products. Therefore it is not out of reason that the United States Government should take a parental interest in its great benzol production, and the use of same for such purposes as the manufacture of aniline dyes for its American consumers and the manufacture of explosives for its own protection should it become necessary. Certainly such a matter is well worth considering by our administration if it is impossible to secure added tariff protection on the lines mentioned so many times in this address.

The South American Handbook, published by the National Foreign Trade Council of 64 Stone Street, New York City (76 pages, price 25 cents per copy), gives detailed information relating to government finances, railway development and foreign trade of the different South American countries. It also contains a report of the Latin-American trade committee on policy required for extension of our commerce and should prove of value to those interested in the development of United States trade with South American countries.

Slime Agitation and Solution Replacement Methods at the West End Mill, Tonopah, Nev.[1]

BY JAY A. CARPENTER

This paper deals with only one step in the treatment of ore at the West End mill; not because the other steps are repetitions of practice in other mills, but because in this particular step there is in use the Trent agitator. This device, although it has apparently failed in many mills, is here giving excellent service and has proved to be well adapted for making a thorough replacement of pregnant solution with a minimum amount of barren solution. The strong and weak points of this agitator, its present simple construction, and its use as a thickener for agitator or battery pulp are features of interest; but perhaps the point of greatest interest to the metallurgist in this day of continuous decantation is its use in a series of tanks for slime treatment by the replacement method.

The agitating department of the West End mill consists of six redwood tanks, 24 ft. in diameter, 18 ft. high, each equipped with a Trent agitator, a centrifugal pump, and a motor. The pulp is transferred by a pump from the top of a flat-bottomed tank to a set of arms and nozzles in the bottom of the tank, at just sufficient pressure to cause the arms to revolve. The streams from the many nozzles keep the bottom of the tank clean, and these streams, coupled with the effect of the revolving mechanism and the ascending current, keep the pulp in constant motion and of constant gravity.

These agitating tanks hold 90 tons of dry slime and 202 tons of solution with a 1.24 pulp, our ore having a specific gravity of 2.7. This capacity is about 10 per cent in excess of the standard 15 by 45 ft. Pachuca tank. The tanks are connected in one series for continuous agitation, the pulp for each agitator being drawn by its pulp through a branch suction from near the top of the preceding tank and delivered to the bottom of the tank by the agitator arms along with the regular pulp of that agitator. This method works automatically, since the flow through the branch suction varies directly with the difference in head of the two tanks. The chance for new pulp to pass out quickly is, therefore, much less than in many other systems of continuous agitation, since the new pulp is delivered at the bottom of the tank, and the discharge from the tank is near the top; the ascending current is uniform and slow.

The pulp is delivered to the first agitator of the series at a gravity of 1.26 by a set of diaphragm pumps, which raise the pulp to a height of 10 ft. above the top of the battery-pulp thickeners, whence it flows first in an open launder and then in a pipe to the suction of the first agitator pump. At intervals in the open launder are placed pieces of battery screen at an angle, which, with those placed at the lip of the diaphragm pumps, catch and remove nearly all the lime scale, wood pulp, and like material from the slow-traveling thickened pulp.

The pulp from the last agitator is raised by an air lift to a Dorr thickener, 28 ft. in diameter and 22 ft. deep, where the pulp it thickened before filtering.

The slaked lime and half the lead acetate are added direct to the scoop box of the tube mills, while the greater portion of the cyanide and the rest of the lead acetate are added at the lip launder of the diaphragm pumps; the remainder of the cyanide is added in the third agitator. For heating the pulp, live steam is introduced into three of the agitators, Nos. 1, 3, and 5, the purpose being to keep the temperature during agitation

[1] A paper presented at the San Francisco meeting of the American Institute of Mining Engineers, September, 1915.

around 100 to 120 deg. Fahr., in order to hasten extraction and obtain good extraction with the use of lower-strength cyanide solutions. These high temperatures are readily maintained in a Trent agitator and are not uncomfortable to the operators, since the heavy coat of foam on the agitators acts as an insulating blanket, keeping the pulp from radiating its heat or moisture, as it does in many other types of agitators. The condensed steam adds to the tonnage of mill solution, but it freshens the solution by dilution of impurities and it is needed to replace the solution that is mechanically lost from the filter.

Once a day, at 4 a. m., pulp samples are taken from agitators Nos. 1, 3, 5, and 6, which are thoroughly washed and dried and made ready for the assayer at 7 a. m. Normally, these assays show respectively 50, 25.5, 19 and 15 per cent of the valuable content of the agitator heads.

Air for the proper aeration of the pulp is compressed to 16 lb. in a compressor of 100 cu. ft. piston displacement, and is fed into the discharge pipe of the agitator pumps. By the time the air is discharged from the

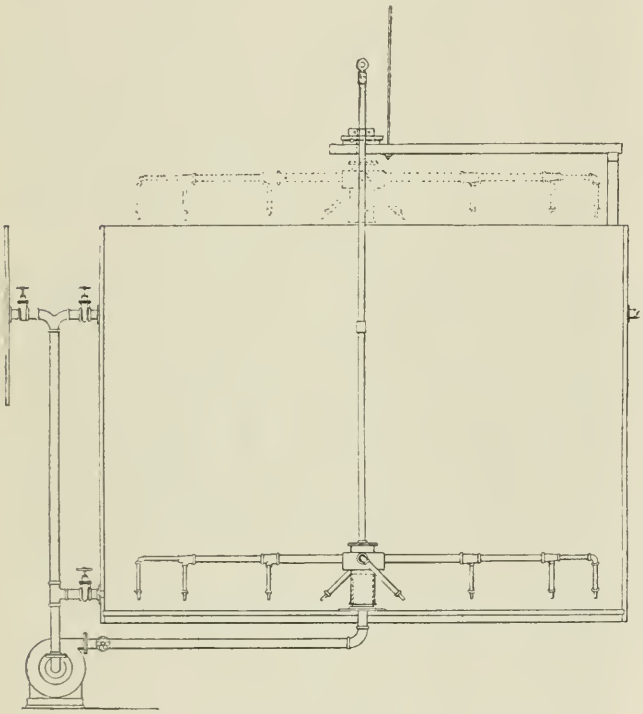


FIG. 1—TRENT AGITATOR, CARPENTER TYPE

nozzles it is thoroughly dispersed in the pulp as minute air bubbles. These air bubbles slowly make their way to the surface and escape into the foam. This well-distributed aeration, in contrast to the short contact of pulp with air in any air-lift type of agitator, is much in favor of the Trent. The pumps of the agitators can be made to suck their own air by throttling the main pulp suction, but in a large installation it is probably more economical to use an air compressor.

Modification of Original Trent Agitators

The original agitators as installed in 1911 were of the Trent underfeed type, with the large grit-proof bearing in the bottom of the tank and with the arms fitted with fifteen ¾-in. nozzles. While these agitators gave excellent service, there was a gradual wear, which necessitated repairs on the grit-proof bearing, due to absorption of the air in the air chamber and consequent rise of slime pulp to the ball race. An occasional cleaning of the nozzles was also necessary, due to their choking with bits of wood pulp, waste, and chips, as a nucleus, surrounded and packed tight by sand from the pulp. On a charge system these repairs could be taken care of easily when the tank was emptied, but when the continuous system was adopted it was necessary once in two or three months to empty each agitator into the following unit by the aid of the transfer pump, and make these repairs, to avoid the danger of an agitator stopping at a time when there was not room in the mill circuit to empty it.

The author, after seeing a Trent agitator suspended from a ball race at the Tonopah Extension mill, because the lower submerged ball race was worn out, conceived the idea and built a new type of this agitator which could be raised, cleaned, and dropped back into position without disturbing the pulp level in the tank. It consisted of a ball race, on timbers over the center of the agitating tank, from which the agitator mast, built of 3-in. pipe, was suspended, a collar clamped around the upper projection of the pipe resting directly on the ball race (Fig. 1).

At the same time, the large upper and lower castings, weighing 800 lb., were discarded, and castings weighing 300 lb. were substituted, which were fitted with extra heavy pipe nipples to serve for the slip joint between the stationary pump discharge and the revolving arms. The upper nipple was of 8-in. pipe, 12 in. long, and was made bell-shaped at the bottom. The lower nipple was of 7-in. pipe, 10 in. long, chamfered at the top. These nipples, after a skim cut in the lathe, have 1/64-in. clearance between them and about a 9-in. contact, which allows only a small flow of pulp to pass between them, but permits the agitator to be raised 9 in. before disengaging. An eye bolt was fastened in the roof directly over the center of the tank, and by means of a chain block the agitator is readily raised above the top of the pulp, where every part of the agitator, excepting the 7-in. nipple in the base casting, can be inspected, cleaned and repaired if necessary. Due to the balanced arms, the bell-shaped nipple, the plumbed point of support, and the guiding ball race, there is no difficulty in lowering the agitator and again engaging the nipples.

The first agitator of this type was placed in commission on Oct. 20, 1913. On account of its lighter weight, it traveled faster and put very little weight on the ball race, as the upward reaction from the nozzles nearly counterbalanced the weight. It was raised, cleaned, and lowered with ease. The tank was emptied at first every couple of months to examine the nipple wear, which was found to be very small. The original pair of nipples, after 19 months' service, are still in use and the wear has not affected the speed of the agitator.

After a thorough trial this new type of agitator was placed in all the tanks at convenient times. It has never been necessary to empty an agitator tank because of failure of the agitator of this type to revolve or keep the pulp agitated. The oldest agitator of this type had operated 10 months (on May 15, 1915) and three others nine months without lowering the pulp in the tank; and, judging from the speed of rotation and the feel of the bottom of the tank, they are good for months to come. When the agitator has been in operation for from four to eight weeks a rod drawn along the tank bottom will strike ridges, which are indications of choked nozzles. After raising the agitator and cleaning out an average of a half-dozen choked nipples, the agitator is lowered to within 6 in. of its usual depth until the cleaned nozzles have cut away the ridges. These agitators have been shut down for hours at a time and have started off after a few minutes' aid in making the first revolution.

This new type of agitator has now been adopted by

the Trent Co. as its standard design, adding to the previous good points of this agitator those of simplicity, durability and reliability.

The pump used on the agitator is a 4-in. centrifugal, driven by a 10-hp. motor. This pump, made by a local foundry, is lined, and has a white-iron open runner. The liners have given an average of eight months and the runners and shafts of six months; the cost of upkeep of the pump is about $5 a month. At first the pumps were driven at 525 r.p.m. and required 6.5 hp. At present the speed is 460 r.p.m., taking 5.8 hp. and keeping the pulp all of the same specific gravity with the aid of the 1.2 hp. used for compressed air. The speed can be dropped to 360 r.p.m. with good agitation, but not with the constant specific gravity desired for continuous agitation. There is often a false economy in cutting power costs of grinding or agitation a cent a ton, with a probable consequence of twice that loss in extraction. The actual power used, figured as motor input, is 7 hp. per agitator, or about 1 hp. for each 12 tons of ore or 42 tons of pulp. At the Goldfield Consolidated mill 200 tons of ore in a 1.5 to 1 pulp has been agitated for 7½ hp. or 1 hp. for 26 2/3 tons of ore or 66 2/3 tons of pulp.

Causes of Failure of Early Agitators

Several of the earlier failures of the Trent agitator were due to too small an area of nozzle discharge and to improper sizes and speeds of the pumps used. The following tests will illustrate some of the points governing the Trent agitator. With the agitator equipped with 15 ¾-in. nozzles, with the pump running at 450 r.p.m., and with 3 ft. of pulp in the tank, the pressure on the pump discharge was 7¾ lb. With the pump stopped, the pressure from the static head on the discharge was 1½ lb. The actual increase of pressure, due to the pump, was 6¼ lb. With the pump running and the discharge valve slowly closed, the pressure increased to 15 lb. and the power decreased one-half. With the agitator run under similar conditions, but equipped with 1½-in. nozzles, giving four times the discharge area, the pressure on the discharge pipe was 2½ lb., or only 1-lb. increase of pressure above the static head; yet the agitator turned at the same speed of 2 r.p.m. and the motor input of 5.6 hp. remained the same.

The reason for the power remaining the same is that a centrifugal pump, running at a given speed, takes approximately the same horsepower for a wide range of heads, but the efficiency, it is to be remembered, varies greatly within this same range. The reason for the agitator running at the same speed is that the greater volume pumped in the second case, acting under less pressure, exerted as much turning force as the lesser volume under greater head.

Figuring from nozzle formula, the quantity discharged in the second case was twice that in the first case, giving, therefore, twice the upward velocity in the tank. The stronger the upward velocity, the more uniform the specific gravity of the pulp. It is evident, therefore, that a large nozzle area, with a pump designed for handling a large volume at a low head and slow speed, is the best combination, and such a pump, made along the lines of the modern Traylor sand pump, should not need repairs for a period of a year. In both the above cases, as the agitator was filled from 3 ft. in depth to 17 ft., the pressure on the pump discharge increased, but nearly in the same amount as the static head, giving the same difference or actual working head, the same power, and the same agitator speed. Consideration of these points takes the successful installation of this agitator and its pump out of the realm of guesswork.

Replacement of Pregnant Solution

At times, when the mill heads were high, it became necessary to replace pregnant with barren solution. The battery-tank solution fed to the glands of the pumps acted as an increasing diluent in the continuous circuit, but did not remove pregnant solution. The top suction of the agitator is about 4 ft. below the top of the tank, and by cutting off the air to the agitator this top 4 ft. becomes a static thickener, ending abruptly in the moving pulp at the agitator suction line. The pulp in the tank from this line down will have a constant gravity without the aid of the air. A decanting pipe placed in this top 4 ft. of the agitator removed the pregnant solution direct to the silver tank. The decanting of a full 3-in. pipe stream can begin thirty minutes after the air is turned off.

With a crowding of tonnage for several months to over 200 tons a day, which was beyond the capacity of the thickeners ahead of the agitators, the overflow of the four 8-ft. Callow cones in the concentrating department was diverted from the thickeners direct to a well, 2 in. in diameter and 3 ft. deep, in the center of the above agitator, which was No. 2 in the series. This pulp was very thin and contained the lightest particles of the ore; yet, with all this pump flowing into the top, this agitator delivered the mill flow of ore in a thicker pulp and of a lower value of solution to No. 3 agitator than it received from No. 1, and, while keeping its pulp in constant agitation for 14 ft. of its depth, it delivered a clear stream of pregnant solution to the silver tank.

At another time for several months, with less tonnage but a higher grade of ore, No. 4 agitator was fitted with an overflow launder, and a well, 2 ft. in diameter and 4 ft. deep, to take the feed from No. 3 agitator. The agitator was run without air, with top suction closed, bottom suction open, and a bottom discharge to No. 5 agitator. The pump entered the agitator at 2½ to 1, and was discharged at 1 to 1 to agitator No. 5, where barren solution was added. The extraction in the tank remained the same as before, when it had air, which, in my opinion, was due to the fact that the greatest extraction had taken place by the time it reached this agitator, and the air included in the pulp was sufficient for extraction.

I have known a Dorr thickener, placed in the middle of a series of agitators, to make a greater extraction than the preceding agitator. However, when the air has been cut off No. 1 Trent agitator in our series, only half the usual extraction has been made. The No. 4 agitator pump on this work was cut to 340 r.p.m., taking 3.5 hp.; yet the agitator started up in its 1.45 pulp after a shutdown as rapidly as the other agitators with only 1.25 pulp. The reason for this is that as the gravity increases the viscosity also increases, hindering the settlement of the heavier sandy particles, which are further handicapped by a diminished difference in gravity between themselves and the surrounding pulp. On this basis, with a proper thickening of the pulp, pyrite concentrate can be readily agitated in a Trent agitator, as is being done at present at the Original Amador Consolidated Mines Company mill at Amador, Cal.

The next and final step in replacing of solutions was proposed to us by L. C. Trent, the inventor of the agitator. The idea was to feed to the agitator pump a ton of barren solution for each ton of ore fed to the tank, to overflow from the tank the whole tonnage of solution fed to it, and to discharge a 1 to 1 pulp from the bottom of the tank, the solution in which should be the barren solution fed to the pump.

This was to be secured by feeding the new pulp to a distributing umbrella on the surface of the pulp in order to feed it in a thin sheet, traveling nearly horizon-

Table I

Time Date Shift	Pulp Feed								Overflow Solution			13 Ft. Valve		9 Ft. Valve		4 Ft. Valve		Pulp Discharge								Replacing Solution		
	Sp. Gr.	Ratio Solution to Ore	Ore			Solution												Sp. Gr.	Ratio Solution to Ore.	Ore			Solution					
			Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.	Sp. Gr.	Oz. per Ton	Sp. Gr.	Oz. per Ton	Sp. Gr.	Oz. per Ton			Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.
First Test:																												
1/28 3-11	1.24	2.25	22.7	4.90	122	51.2	7.91	405	70.0	6.66	466	1.05	5.66	1.29	4.99	1.41	2.41	1.38	1.29	5.1	4.13	21	6.6	2.10	14	14.0	0.20	3.0
11-7	1.23	2.37	21.9	4.56	100	51.8	7.41	384	61.0	6.60	402	1.05	5.63	1.23	4.04	1.43	2.34	1.45	1.03	10.2	4.17	42	10.4	2 22	23	18.7	0.20	3.7
7-3	1.21	2.63	24.2	4.14	100	63.8	7.02	448	50.0	6.47	323	1.05	5.82	1.07	4.88	1.42	2.40	1.42	1.13	26.5	4.01	106	30.0	2.17	65	20.2	0.23	4.6
24 hr.	.....	.....	68.8	4.68	322	166.8	7.42	1,237	181.0	6.58	1,191	.....	.....	.....	.....	.....	.....	.....	.....	41.8	4.07	169	47.0	2.19	102	52.9	0.21	11.3
1/29 3-11	1.19	2.95	18.1	4.02	72	53.1	6.82	362	74.0	6.36	471	1.06	6.29	1.06	6.04	1.45	3.00	1.43	1.10	21.4	4.02	87	23.6	2.60	61	16.3	0.27	4.4
11-7	1.21	2.63	18.6	4.49	83	49.1	6.88	338	34.0	6.35	216	1.06	6.50	1.07	6.25	1.49	3.20	1.46	1.00	22.9	3.93	90	22.9	2.73	62	15.3	0.29	4.4
7-3	1.20	2.78	21.5	4.41	95	59.9	6.82	408	50.0	6.83	341	1.06	6.59	1.09	6.25	1.45	3.10	1.42	1.13	29.5	3.91	114	32.9	2.60	85	25.0	0.29	7.5
24 hr.	.....	.....	58.2	4.31	250	162.1	6.83	1,108	158.0	6.50	1,028	.....	.....	.....	.....	.....	.....	.....	.....	73.8	3.95	291	79.4	2.62	208	56.6	.....	16.3
Second Test:																												
3/7 24 hr.	1.25	2.15	63.6	2.23	142	108.0	5.62	607	120.0	4.40	530	1.07	4.59	1.17	4.44	1.47	1.83	1.46	1.00	43.4	1.70	74	43.4	1.52	66	50.4	0.16	8.0
3/8 7-3	1.25	2.15	22.7	.....	.....	49.0	6.84	.....	50.0	.....	.....	1.09	.....	1.12	.....	1.45	.....	1.43	1.08	22.8	.....	.....	24.4	1.30	32	25.5	.....	.....
3-11	1.22	2.50	21.5	.....	.....	54.0	6.84	.....	51.0	.....	.....	1.09	.....	1.10	.....	1.46	.....	1.46	1.00	24.0	.....	.....	24.0	1.52	36	21.3	.....	.....
11-7	1.23	2.37	18.6	.....	.....	44.0	6.84	.....	45.0	.....	.....	1.11	.....	1.11	.....	1.48	.....	1.48	0.94	20.4	.....	.....	19.2	1.58	30	20.2	.....	.....
3/8 24 hr.	1.23	2.34	62.8	2.32	146	147.0	6.84	1,005	146.0	5.20	760	.....	5.24	.....	4.60	.....	1.91	.....	.....	67.2	1.92	129	67.2	1.46	98	67.0	0.16	10.7
3/9 7-3	1.23	2.37	19.0	.....	.....	45.0	.....	.....	.....	.....	.....	1.09	.....	1.10	.....	1.45	.....	1.46	1.00	19.5	.....	.....	19.5	1.63	32	23.9	.....	.....
3-11	1.21	2.63	17.9	.....	.....	42.0	.....	.....	.....	.....	.....	1.10	.....	1.12	.....	1.48	.....	1.48	0.94	13.5	.....	.....	12.5	1.72	21	24.0	.....	.....
11-7	1.23	2.37	16.5	.....	.....	43.0	.....	.....	.....	.....	.....	1.10	.....	1.10	.....	1.48	.....	1.49	0.92	13.3	.....	.....	12.2	1.70	21	22.6	.....	.....
3/9 24 hr.	.....	.....	53.4	2.32	124	130.0	6.80	882	155.0	5.60	866	.....	5.72	.....	5.63	.....	2.36	.....	.....	46.3	1.92	89	44.2	1.68	74	70.5	0.50	10.5
3/10 7-3	1.20	2 78	16.8	.....	.....	45.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.48	0.94	13.0	.....	.....	12.2	1.53	19	19.0	.....	.....
3-11	1.20	2.78	19.1	.....	.....	53.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.47	0.95	20.2	.....	.....	19.0	1.45	27	24.6	.....	.....
11-7	1.19	2.95	20.6	.....	.....	61.0	.....	.....	.....	.....	.....	1.09	.....	1.10	.....	1.52	.....	1.51	0.87	17.3	.....	.....	15.0	1.67	25	22.0	.....	.....
24 hr.	.....	.....	56.5	2.24	126	159.0	5.66	900	184.0	5.30	970	.....	5.28	.....	5.02	.....	1.80	.....	.....	50.5	1.90	96	46.2	.....	71	65.6	0.16	10.5
3/11 7-3	1.18	3.13	18.0	2.24	40	56.0	5.62	314	55.0	5.39	296	.....	5.30	.....	5.00	.....	1.90	1.50	0.89	20.9	1.90	39	18.7	1.37	26	22.0	0.17	3.7
Totals:																												
First Test.	.....	.....	127.0	4.50	572	328.9	7.13	2,345	339.0	6.54	2,219	.....	.....	.....	.....	.....	.....	.....	.....	115.6	3.98	460	126.4	2.46	310	109.5	0.25	27.4
Second Test....	.....	.....	254.3	2.30	585	600.0	6.18	3,708	660,0	5.17	3,416	.....	.....	.....	.....	.....	.....	.....	.....	228.3	1.87	427	219.7	1.52	335	275.5	0.16	43.4

tally, and by having the bottom suction draw pulp from all over the tank by means of a perforated bustle pipe inside the tank, these two doing away with all strong currents. A bypass between the discharge and the suction of the pump would regulate the speed of the agitator, and a series of manifold valves would regulate the flow of barren solution to the pump. A 1 to 1 pulp would be established in the bottom 6 ft. of the tank, and above this a sharp change to thin pulp, and then to clear solution at the top of the tank. The new pulp entering the tank would enter on the surface, only causing a ripple. The solid content would settle through the clear zone into the thick pulp below, but the solution would overflow into the launder, since there would be no downward current, due to the fact that as much solution was introduced at the bottom of the tank as was removed. For a similar reason, the solution fed in at the bottom would find no rising current, and, being mixed with the pulp, would be discharged as an integral part of the discharge pulp. By this method, the inventor reasoned that it would easily be possible to make a 90 per cent replacement of the dissolved silver entering the tank.

At the time of this visit, every agitator was needed for agitation purposes, the canvas-leaf filter was doing good work, and, lastly, we had little faith in making a high replacement of pregnant solution by this method, for all the many efforts along this line had been failures; and it was generally conceded that the diffusion of solutions of equal gravity took place so quickly and so completely that such a scheme was not practical. However, these replacers were installed at the Gold Cross and Imperial Reduction Company plants near Ogilby, Cal., and news of their successful operation came to us not only from the company headquarters, but from the traveling fraternity of millmen looking for a job.

In February, 1915, with a decrease in tonnage, No. 4 agitator was fitted up for a trial as a replacer. With the agitator filled with 1.20 specific gravity pulp, containing 203 tons of solution assaying 7 oz. silver, the feed of pulp and the air were cut off, and the bottom suction opened. Three hours later, when the pulp in the bottom of the tank reached 1.36 specific gravity, a flow of barren solution, assaying 0.13 oz. silver per ton, was admitted to the pump at the rate of about 3 tons an hour. At the end of twelve hours the gravity at 4 ft. from the bottom was 1.36, at 8 ft., 1.11, and at 12 ft., clear; and the solution assays were 3.94, 4.57 and 6.97 oz., respectively. In thirty-six hours there had been added a little over 100 tons of solution, and the specific gravity at 4 ft. from the bottom was 1.34; at 8 ft., cloudy; at 12 ft., cloudy, and the overflow clear; and the solution assays were 1.79, 2.52, 6.21 and 6.6 oz., respectively. Since there was no discharge from the tank, the addition of barren solution had to be slow to keep from thinning the pulp in the bottom of the tank. The replacing action is distinctly shown by the assays. At the end of this time pulp feed and pulp discharge were started into and from the replacer. The results of the next two days' work are shown in Table 1.

The sharp reduction in the value of the ore, due to the extraction made in the replacer, makes it difficult to calculate the efficiency of the replacement, but, since most of the ore is in the bottom 6 ft. of the tank in the barren-solution zone, it is probably true that most of the dissolved silver goes out with the discharged solution.

During the second day there was more solution discharged from the tank than barren solution fed into the pump, and the effect is shown by the assays.

On the third day the agitator slowed down, and shutting the bypass did not increase the speed; yet the turning pressure of a man's hands on the ball race would turn the agitator faster. It pointed clearly to a choked suction pipe, which, with an inventor's optimism, was submerged under 12 ft. of pulp. Not being able to continue the experiment, the top suction was opened and the agitator started off at 3 r.p.m. The result of the experiment demonstrated that a barren zone could be maintained in the bottom of the tank and a high percentage of replacement made, but it also showed that

the capacity of the 24-ft. tank was limited to 60 tons of ore per day at a 2½ to 1 dilution, in order to keep a clear overflow, and proved that the mechanical arrangement was defective.

Mechanical Defects Remedied

To improve the mechanical defects, the author designed both a new arrangement for the incoming pulp and a new suction for the replacer pump. Instead of the umbrella, a well, 2 ft. in diameter and 4 ft. deep, was placed at the center of the tank around the mast. The bottom was made solid and the sides perforated with ¾-in. holes. An arm was put on the mast, which kept the bottom of the well clear.

The suction of the pump was carried around the outside of the tank as a bustle pipe, with the diameter proportioned to the flow. Twelve 1½-in. branches entered the tank at the floor level and ended at varying lengths in upturned ells. Each branch suction was connected to the main pipe by a plug cock, and each had a ¾-in. connection for testing the flow and for connecting high-pressure water if it was choked.

On March 5, 1915, the replacer was started again with these changes. The new well still introduced the incoming pulp horizontally, but below the surface, giving a greater distance down to the slime line at the overflow launder. The new suction made it possible to test and keep open the twelve suction ports at all times, and left nothing inside the tank to give trouble. The agitator, being the new style, was capable of being raised out of the tank for cleaning the nozzles, and for repairs if necessary, and dropped back without affecting the solution zones in the tank. In starting the experiment, the introduction of the barren solution, as before, gradually established a barren zone, or, rather, in this case, a zone of low grade at the bottom, increasing value upward in the tank. This suggests a method for very small plants, such as used on old dumps, of using the replacer as a thickener first, an agitator second, and lastly as a replacer, discharging after making a second replacement with water. After establishing the barren zone, the feed into and discharge from the replacer were started, and the results obtained are shown in Table I.

A detailed study of the table brings out many interesting features of the replacer. A feed of replacing solution considerably in excess of discharge solution for the period of a shift results in a marked lowering of the solution value in the thick pulp and a decrease in that of the thin pulp, while the opposite condition of feed will increase the value likewise. The sharp change in the silver content of the solution is between the thick 1 to 1 pulp and the thin pulp above it, for the reason that the diffusion in the thin pulp is rapid. Hence, there is no advantage, in installing a replacer, in having any more depth above the 6 ft. of thick pulp than is necessary for the settling of the ore. It is possible to discharge the pulp thicker than 1 to 1, but it takes more power applied to the pump to turn the agitator. With a positive drive overhead, taking very little power, the pulp could be discharged as an 0.8 to 1 pulp or thicker with better replacing results.

In order to calculate the replacement of solutions in these tests, two methods are used as checks: First, dividing the ounces overflowed by the ounces fed; second, dividing the ounces discharged by ounces fed. However, before doing this, the ounces extracted from the ore and the ounces fed in with the replacing solution should be divided between the ounces overflowed and ounces discharged. These two items amount to considerable in our tests, because we were not equipped to add barren solution, and, secondly, the ore still lacked sufficient agitation to be ready for filtering. Since the replacing solution is fed to the bottom of the tank, and assays show that it remains there as a partly barren zone, and since over 90 per cent of the ore is in the bottom half of the tank and a large part of it in contact with the barren replacing solution, it is fair to presume that over 80 per cent of the replacing solution and ore extraction go out in the discharge and 20 per cent reaches the overflow.

In the first test, 27 oz. of silver was introduced with the replacing solution, and 112 oz. of silver was yielded to the solutions by the ore, or a total of 139 oz., 20 per cent of which is 28 oz. and 80 per cent 111 oz. Silver to the amount of 2345 oz. was fed with the pulp solution, and of this 2219 oz. less 28 oz. was overflowed, giving 93.2 per cent replacement. Figuring by the second method, of the 2345 oz. of silver fed, only 310 oz. less 111 oz. of it was discharged, giving 91.5 per cent replacement.

In the second test 43 oz. of silver was introduced with the replacing solutions and 158 oz. of silver derived from the ore. The silver fed with the pulp solution was 3708 oz. and of this 3416 oz. less 40 oz. was overflowed, giving 93.2 per cent replacement. Figuring by the second method, of the 3708 oz. fed, only 335 oz. less 160 oz. of it was discharged, giving 95.3 per cent replacement.

In actual practice there is always a little silver in the replacing solution, and, as has been found in the continuous-decantation method, there is always an extraction from the ore, no matter how long it has been treated before decantation. These items were not considered in the foregoing calculations, as they were exceptionally high under our conditions. Again, in the tests, 11 per cent more replacing solution was added than was discharged, which could not be done with the final water replacing, due to the building up of solution tonnage.

Conclusions Drawn from Experiment

However, it was established to our satisfaction:

1. That replacing with the Trent apparatus is practicable.

2. That it is easy to control and regulate the replacer; the one important factor being to regulate the solution fed to the pump and that discharged from the replacer. In a plant designed for this system this would be a much easier matter than in our case.

3. That on a quick-settling pulp it would handle a remarkably large tonnage as far as adding the necessary barren solution is concerned, but that on a pulp carrying a fair percentage of light, flocculent slime it is limited in tonnage to the rate at which the light, flocculent slime will settle in a neutral or no-current tank. In a Dorr thickener there is a downward current to aid settling. At the new mill at Aurora, Nev., the light slime hardly settled in a Dorr thickener, and practically remained in suspension in the Trent replacer.

4. That mechanically the replacer worked very satisfactorily, but that changes could be made to cut down the power consumed and yet make the rotating action more positive.

5. That with a mixture of Tonopah ores, 60 tons of ore in a 2½ to 1 pulp, with 60 tons of replacing solution, was all that a replacer 24 ft. in diameter and 18 ft. high could handle with a clear overflow and a 1 to 1 discharge.

The use of this agitator for replacer experiments necessitated by passing all but 60 tons past this agitator, and caused a loss in extraction that made it necessary to stop the experiment without a working test extending over a few weeks' time; but the author believes the same results would have continued, as everything about the installation was capable of easy adjustment and repair.

Before changing back to an agitator, the replacer was run as an ordinary thickener with a 1 to 1 discharge, all replacing solution and gland water being cut off the pump, and the speed of the agitator cut to one revolution in five minutes. Hose lines were strung to add a large tonnage of solution to the 60 tons of ore in a 2½ to 1 pulp. To run as a thickener and make 90 per cent replacement with a 1 to 1 discharge, the 60 tons of ore would have to be diluted to a 10 to 1 pulp by the addition of 450 tons of barren solution to the 150 tons of pregnant solution. About a 7 to 1 pulp was all that could be supplied without interfering with mill operations, but the slime line rose rapidly from 4 ft. below the surface up to the overflow launder. The 60 tons capacity of the replacer had appeared disappointing, but the test showed it to be a good tonnage on this particular ore compared with replacement by dilution; but it also confirmed the author's conviction that on an ore containing considerable flocculent slime the various replacing methods will have a strong rival in the older leaf and pressure filters that make an easily washed cake from the mixture of the flocculent and sandy components of the ore.

The great advantage of the replacer over the thickener-dilution method is in the smaller installation required, and the small amount of barren solution required compared with the large tonnage of barren and partly barren solution of the dilution method.

The main drawback to the replacer system has been, first, lack of faith in its principles, and second, lack of faith in its mechanical features.

To one that has operated the replacer it is easy to understand that in a 1 to 1 and thicker pulp, the pulp is so thick that the ore and solution are approaching a solid, and that the viscosity of the pulp is so great that the solution is not free to move above amid the ore particles, but, rather, is constrained to move with them; and that, once the barren solution is whipped into the pulp by the pump, it tends to remain locked up in it. The pump is of such a size that the difference in specific gravity between its suction and its discharge is only a couple of hundredths, so that the discharge pulp has no tendency to rise in the tank. This explains why the Trent method is a success and why other methods of adding the replacing solution directly into the bottom of a tank have failed.

The last year has brought about a marked improvement in mechanical simplicity and reliability in the mechanism of the replacer. One strong objection to it, compared with the dilution system, is the power required to operate it. However, this does not seem excessive when one considers the saving of the power that is consumed in handling and precipitating the large tonnages of solution required by the dilution methods. The author believes the power consumption of the replacer can be made nearly as low as that required by the equivalent number of thickeners, by the simple device of not depending entirely upon the pump to rotate the agitator, but to drive the agitator from overhead by a worm drive similar to that of the Dorr thickener and to use the pump more as a mixer and circulator of pulp, running it at a slower speed and with larger nozzles on the agitator. Our experience was that it required about 3 hp. on the motor to turn the agitator at only 1 r.p.m. in a 1 to 1 pulp, when a man with a 1-ft. leverage on the mast could turn it with ease. Why, then, should pump nozzle velocity be relied upon to turn the agitator when its proper function should be that of mixing the barren solution into the pulp and giving only the turning effect derived from that function? The pump, with a slower speed and lower working head, should need only annual repairs.

With these modifications, the author believes that the replacer will become an accepted machine in the treatment of slime that is not too colloidal in its nature.

Tonopah, Nev.

The Necessity of Tariff Reform for the American Chemical Industries

The necessity of tariff reform for the chemical industries was the subject of quite a number of lectures at the National Exposition of Chemical Industries, held in New York City, from Sept. 20 to 25. One phase of the problem, the necessity of a really strong and efficient Tariff Commission, was the subject of two addresses, made by Mr. Howard H. Gross on the afternoon of Sept. 21, and at the meeting of the American Chemical Society, in the evening of Sept. 24.

Mr. Howard H. Gross, a banker in Chicago in private life, is the president of the Tariff Commission League. He emphasized that tariff tinkering must stop. In thirty years of "tariff tinkering" we have had five revisions of the tariff and two attempts at revision. The result has been that nobody is satisfied, that business has been periodically upset, that hundreds of millions of money have been lost and millions of workers distressed.

The tariff must be taken out of politics. This is absolutely necessary. What is needed to accomplish it is a permanent nonpartisan tariff commission, a sane tariff policy and scientific adjustment.

The Tariff Commission League has been founded to inaugurate and carry forward a nationwide campaign of education, to create and crystallize a public sentiment that will demand of Congress the establishment and permanent maintenance of a nonpartisan tariff commission of the highest personnel, with long tenure of office and adequate salaries; the commission to have broad powers covering investigation, gathering of tariff data, making reports and recommendations to Congress, hearing complaints, etc., to the end that tariff enactments shall be in the interest of all the people from the standpoint of sound economics rather than political expediency. The final decision as to rates will, however, be with Congress.

It is proposed that this Tariff Commission be composed of seven members, to be appointed by the President and confirmed by the Senate. In the make-up of the commission, one member is to represent agriculture, one industrial labor, one manufactures, one trade and commerce, one is to represent higher education and have special training for scientific investigation and research, and one is to be experienced in tariff classifications and familiar with departmental rulings in tariff matters. No one political party shall have a majority of the members of the commission. No member of Congress, or one who has served in Congress within two years, shall be eligible to appointment.

Mr. Gross emphasized that public sentiment is the strongest force in the world. What the people really want and insist upon, they will get. That is the reason why they got civil service. And they will get a real strong Tariff Commission if they insist upon it.

* * *

Another phase of the tariff reform which is necessary for the aid of the chemical industries of this country—that is, a scientifically devised protective tariff, sufficiently high and for a sufficiently long time—was the subject of a number of speeches, especially of the elaborate address by Mr. I. F. Stone, on the aniline dye situation. This is printed in full on page 663 of this issue.

Applied Chemistry*

BY L. H. BAEKELAND

It is only three years ago that a Brooklyn alderman, who, in the absence of the Mayor of New York, had to welcome the visitors to the International Congress of Chemistry, addressed them as if they were druggists or pharmacists.

After all, he made not much greater a mistake than many so-called educated men who obtained a B.A. and yet are ignorant enough of elementary scientific knowledge to imagine that the main occupation of a chemist is to analyze substances and detect falsifications.

Even in England, a pharmacist is currently designated as "chemist," while a real chemist is called an "analytical chemist."

But the European war has done much to correct some of these mistaken notions of the public at large. Our daily press has now more or less acquainted this country with the fact that in our national make-up, there is such a thing as chemical problems. I doubt, however, whether the unthinking masses have begun to realize that aside of the so-called chemical industry, practically every other industry, in fact, every enterprise, has chemical questions to contend with, and that chemical industry itself is intimately interwoven with the great network of every modern industrial or agricultural state; that the economic welfare of our country, and the health of its citizens are largely dependent on the way we utilize our chemical knowledge.

CHEMICAL WARS

The present war has been aptly called a "chemical war" because efficient work of every department of the fighting armies, from the Red Cross service to the manufacture of guns and explosives, involves incessantly chemical knowledge—and still more chemical knowledge.

But do not imagine that this is the first chemical war. The art of killing and robbing each other became "chemical" the day gunpowder was invented; at that time, however, the existing knowledge of chemistry was just of pinhead size. Napoleon knew very well how to use adroitly exact knowledge and chemistry for furthering his insatiable ambition to dominate the world; so he surrounded himself with the most able chemical advisers and scientists, and for awhile at least, he placed himself at a decided advantage over his many enemies; incidentally, he thus helped to lay the foundation for some very important branches of chemical industry.

"Les chiens ont appris quelquechose," exclaimed the Corsican conqueror when he realized that his enemies began to adopt the same means which had given him temporary mastership over them; but those whom he called so contemptuously " "the dogs," finally beat him at his own game.

Ever since then, science, technology and chemistry in particular, have played a rôle of increasing importance in the armament of nations. This accounts, perhaps, for the strange fact that the really great military inventions have practically all emanated from civilians and from non-military nations like our own. If the men of the military class, essentially conservative in all countries, had been left to their own devices, they would probably still be fighting with bows and arrows—or perhaps, with the traditional sling. Nor should the pacifist blame the chemist if the latter's most beautiful conquests in science, if his proudest discoveries, have been turned into means of relentless destruction and human slaughter. Do not reproach chemistry with the fact that nitrocellulose, of which the first application was to heal wounds and to advance the art of photography, was stolen away from these ultrapacific purposes for making smokeless powder and for loading torpedoes. Do not curse the chemist when phenol, which revolutionized surgery, turned from a blessing to humanity into a fearful explosive, after it had been discovered that nitration changes it into picric acid.

As well might you curse written speech or language or the art of printing—by which the most noble thoughts of the human race have been expressed, disseminated and preserved—if it has been used also to distribute the vilest lies and the most damnable errors.

Knowledge is like a knife: In the hands of a well-balanced adult, it is an instrument for good of unestimable value; but in the hands of a child, an idiot, a criminal, a drunkard, or an insane man, it may cause havoc, misery, suffering and crime.

Science and religion have this in common, that their noble aims, their power for good, have often with wrong men, deteriorated into a boomerang to the human race. Our very successes will threaten to devour us as long as all of us have not yet become imbued with the truth that greater knowledge, like greater possession of wealth or power, demands a greater feeling of responsibility, greater virtues, higher aims, better men.

Let us hope, in the meantime, that war carried to its modern logical gruesomeness, shorn of all its false glamor, deceptive picturesqueness, and rhetorical bombast, exposed in all the nakedness of its nasty horrors, may hurry along the day when we shall be compelled to accept means for avoiding its repetition.

Will you take it amiss if I made a digression from my subject as an answer to some repeated attacks which have been made of late by men who blame our increasing scientific knowledge in general and our chemical science in particular, for the excesses of the present European war?

THE PEACEFUL WORK OF AMERICAN CHEMISTS

But let us turn our attention to more peaceful chemical pursuits and more particularly to the chemists of this country.

Their work is difficult to understand and still more difficult to be appreciated by the uneducated or uninitiated; nor do chemists court the plaudits of an ignorant public that cannot understand them; they feel fully compensated by the results of their work if it only meets with the approval of a few of their fellow-chemists, irrespective whether it brings them financial results or not; in fact, most chemists are so much in love with their work that very often they neglect the financial side to their own immediate detriment.

Unlike the physician, lawyer, clergyman, actor, writer, artist, or businessman, the chemist does not depend on the public at large; he is either engaged in some private enterprise or he acts in a consulting capacity for a few people, if he is not engaged as professor or teacher in some educational institution. Popularity in the usual sense has little or no value for the chemist.

No wonder then that the chemists of this country, numerous and active as they are, have hardly been noticed among the daily noise of newspaper sensation and shrieking publicity—no more than a skillful watchmaker would be noticed among the hammering of a busy steam-boiler manufacturing plant.

And yet, right here in the United States, the chemical profession has taken such a root, such a develop-

*An address presented at the meeting of the American Chemical Society at Seattle, Wash., and repeated before the National Exposition of Chemical Industries in New York City.

ment during the later years, that we have here assembled at this very meeting, the representatives of our national American Chemical Society, which counts over 7000 members, by far the largest membership of any chemical society in the world, with all due respect to England, France and Germany. A society which finds it possible to spend yearly over $100,000 on its three chemical publications, copies of which are to be found all over the world in every well equipped scientific library.

Nor is the study of the science of chemistry in this country a matter of recent occurrence. Our European friends are astonished when we tell them that as far back as 1792, there existed already the Chemical Society of Philadelphia, which was probably the first chemical society ever organized in the world; even today, some of the papers read at the meetings of that early scientific body furnish very interesting reading. Some of our American universities equipped chemical research laboratories for students as far back as thirty-five years ago, at a time when exceedingly few of the best known European universities possessed any such facilities.

Nor should we overlook the fact that notwithstanding the essentially pragmatic tendencies of our country, the United States has given to the world a Willard Gibbs, who out-theorized existing chemical theories and whose mathematical deductions are still after his death, furnishing food for profound thought to the most renowned physical chemists of Europe to whom they have opened entirely new fields in the study of chemical dynamics.

THE ANILINE-DYE SITUATION

I mention this more particularly because some of our aniline-dye consumers have taken the chemists of the United States bitterly to task and have made decidedly unfavorable comments on their abilities, because since the European war, dyes could no longer be imported from Europe. But Dr. B. C. Hesse, an American-born chemist, a graduate of the University of Michigan, has already ably answered this indictment of the American chemists. In a paper[1] full of information on this subject, which he presented at our last general meeting, but which, unfortunately, has received little or no attention from our daily press, he has clearly demonstrated that the aniline-dye consumers of the United States can have all the chemists and all the dyes they want; provided they are willing to make the necessary investments of capital and to submit to the risk of uncertain profits by starting their own dye-manufacturing establishments here in the United States instead of, as in the past, favoring imported dyes, either through personal choice, or by fostering legislation which forbids the home manufacturers to utilize such methods as selling agreements, "Kartels," or other consolidation of interests, dumping, so as to kill new competitors in the field, while making up the temporary loss by increasing the price of other products, and in general, any of the many other trade-arrangements and trading tricks freely and openly utilized by European manufacturers so as to stifle possible competition of our home aniline-dye producers.

The outcry which has been raised as to our shortage of artificial dyes is out of all proportion if we take in consideration that the annual importation of dyes and synthetic products from Germany amounts only to about $9,000,000. As our former president, Mr. A. D. Little, pointed out, this represents about the same sum of money as the amount of candy sold annually by the Woolworth ten-cent stores.

[1]Met. & Chem. Engineering, May, 1915, page 287.

LOCAL OPPORTUNITIES OF AMERICAN CHEMICAL INDUSTRIES

The development of any chemical industry is a matter of local opportunities; for instance, the manufacture of cellulose, as well as the industry of wood-distilling, has taken a greater development in the wood-covered sections of the United States than in Germany or any other country in the world.

The magnitude and earning capacity of the largest German chemical enterprise, however imposing they may be, look less astonishing if you take into consideration that some of these companies have been in existence for more than half a century. Much younger American chemical enterprises, which make American specialties—for instance, the Eastman Kodak Company, which sends its films and photographic papers throughout the whole world—have annual earnings decidedly greater than the most successful German chemical works of much older existence. Nor is the value of the output of our largest purely chemical companies much less important than that of the German concerns.

SULPHURIC ACID

This country is now the greatest producer of sulphuric acid, with an annual production of about 3,000,000 tons. Yet it is not so long ago that the first maker of sulphuric acid could not even find a purchaser for a triflingly small production of a few tons per week. It needed the opportunity of a home market; by and by this was created by the refining of petroleum after the discovery of our oil fields, the discovery of natural phosphates and the resultant industry of superphosphates, the use of dynamite for blasting, the development of the glucose industry, electrolytic copper refining. These and many other new industries all required large amounts of sulphuric acid, and gave this country an opportunity of developing sulphuric acid manufacturing to its present importance. In fact, the same reasoning holds good for all of our industries. I doubt very much whether the talented foreigners, who have now become proficient in chemical manufacturing, would have tied their initiative and enterprise by specializing in coal-tar-dyes manufacturing, if they had had the limitless opportunities of an immense undeveloped country like ours, to which to give outlet to their spirit of pioneership in mining, transportation, agriculture, and similar subjects, all beckoning for more urgent attention, and offering at the same time, more immediate rewards.

AMERICAN ELECTROCHEMICAL INDUSTRIES

In the meantime some of our other chemical industries better suited to our local conditions, have taken such an enormous development here as to make the United States an undisputed leader in at least some of them. Such products as the various acids and salts, aluminium, artificial abrasives, soda and caustic alkalies, bleaching powder, chlorine products, electrolytic copper, are decidedly more important in value and in economic importance than the few million imported coal-tar dyes.

F. A. Lidbury[2] pointed out rightly that if there had been a shortage in some of the products of our electrochemical industries in which the United States has been a pioneer, the consequences to our national economies would have been so serious that the present complaint of our aniline-dye users would have sounded like a timid whisper, compared to the bellowing lamentations of so many more important industries which would have become absolutely paralyzed. The fact is

[2]Met. & Chem. Engineering, May, 1915, page 277.

that few men realize how many industries are directly dependent on the work of American chemists.

If the aniline-dye industry has been somewhat neglected in this country, there are many other good reasons for it; not only was the possibility of reasonable profits too scant to offer special inducement to clever-headed businessmen to risk their capital in this branch of manufacturing when they had so much better choice in other channels of enterprise, but the first raw material, suitable coal-tar, was not abundantly available here as it is in Europe, for the simple reason that this country long ago discarded the older and more expensive methods of gas manufacturing generally used in Europe, and which give coal-tar as a by-product. The less expensive and simpler water-gas process, adopted in the United States, gives no suitable gas-tar; it is only of late, by the introduction of the by-product coke-ovens that we can look forward to an almost illimited supply of coal-tar.

In the meantime, the German manufacturers had every opportunity in specializing in these coal-tar industries and could afford to concentrate their efforts so as to supply not only their home consumption and that of the United States, but that of the whole world; in about the same way as the United States sends to the remotest corners of the globe, its sewing machines, its typewriters and its Ford cars.

Judging from the past history of the chemical industry in America, I have little doubt that the day it will be found profitable to manufacture all kinds of synthetic dyes here in the United States, instead of a few as is the case now, there will be little further delay in supplying the demand by a hustling and bustling home production.

In fact, it is quite possible that under present abnormal conditions, this branch of manufacturing may be stimulated to the point as to result in over-production after the war is over.

CHEMICAL RESEARCH IN UNITED STATES

If hitherto our chemists have been deficient in this special line, we can, with some satisfaction, point to better efforts in other chemical industries. For instance, it is not sufficiently known how many research chemists in our different American manufacturing establishments, are busily occupied in studying and improving manufacturing processes, nor what large sums of money are devoted every year to industrial chemical research. If we hear it constantly repeated that some of the largest German chemical companies employ hundreds of chemists and engineers, it is less known that right here in the United States, the number of chemists employed in some of our better organized chemical enterprises is scarcely less; but nobody finds it necessary to boast about it.

In fact, the most striking symptom is that so many engineering enterprises, for instance, some of our large electrical companies—although their field of action seems rather remote of chemical subjects—have now elaborate chemical research organizations, of which the record is well known by its excellent results.

Conditions were quite different some fifteen or twenty years ago; but this country has grown, and as the requirements and opportunities grew up at the same time new chemical problems arose thereby.

THE ANALYTIC AND CONSTRUCTIVE TURN OF MIND

The urgent nature as well as the magnitude of some of these new chemical problems, is shaking our chemists awake—is making new men of them. Professor Whitaker is probably right when he says that the chemists are thirty years behind the engineers as far as method and attitude of mind is concerned, but this same criticism holds good for chemists all over the world. The fact is that the engineer was called first, and he was born centuries before the chemist, but the latter is now making up for lost time.

New conditions, new problems, are compelling the chemist to learn to tackle a proposition in a true engineering spirit and—to hitch some business sense to it. He is learning to forget thinking or acting on the test-tube plan; he is thrown more and more in contact with businessmen; he begins to realize that too one-sided theoretical considerations are sometimes more dangerous than complete ignorance and that a sense of proportion and relative values is the first requirement for good practical effort.

Here, indeed, is one of the weakest spots of the chemist. Aside from the fact that the chemical profession seems one of those vocations which have fascinated a large number of intellectual freaks, it has generally attracted men of an analytical, rather than a constructive turn of mind. Successful engineering is essentially constructive. The most urgent work for the chemist of to-day, must be constructive—he must learn how to cement together the vast amount of data which already lie at his disposal, even if he, himself, has to provide this very cement by further research.

THE CHEMIST IN OTHER INDUSTRIES

The chemist of to-day is no longer confined to purely chemical enterprises; even the most stubbornly conservative manufacturers have learned, through competition, that every industry, however mechanical be its nature, has its chemical problems. Things have changed rapidly since the day Andrew Carnegie listened with a sly twinkle in his eyes, to the fun his competitors were poking at him when he first engaged a spectacled professor to investigate the chemical problems in his iron-works. Conditions have now become reversed; to-day a steel or iron-works without a competent chemist justly provokes contempt and distrust.

Nor is the time so far distant when even our biggest railroads had not begun to realize how they missed the constant services of a staff of chemists, so as to advise them in the endless chemical problems which present themselves in the operation of a well organized railroad.

Some time ago, I visited the plant of the National Cash Register Company, in Dayton, Ohio; one of its most interesting departments was its well-equipped chemical laboratory, where no end of chemical questions relating to the manufacture of purely mechanical devices have to be studied and solved.

No up-to-date motor-car works is complete without its chemical department and the same remark holds good for all well organized engineering concerns.

In this country, the importance of chemistry has been first appreciated in its relations to agriculture. So obvious was this, that we set an example to all other nations of the world by the number of our federal and our State chemical agricultural laboratories. This, more than anything else, was the entering wedge of applied chemistry in this country, which extended later on in the Government Service, Geological Survey, Bureau of Standards, and the Bureau of Mines. Nor did the useful effect stop there. Many of our federal-chemists, our State-chemists, have left public service, to accept better paying positions in private industries; but the men trained in public service, implanted their high aims and scientific ways in some of our commercial enterprises, which needed it badly. I know of some cases where this beneficial influence changed radically the whole spirit of the commercial organiza-

tion, from its manufacturing to its selling department, and introduced instead of reckless, sordid commercialism, a spirit of fairness and efficiency which soon proved the more profitable policy.

ETHICS OF THE CHEMIST

In this and similar directions, the chemist can exercise a valuable moral influence on the community. If you think it over, you will find that the quest of efficiency lies quite close to the path of honesty, justice, and equity.

Here also the chemist has much to learn. In some instances I have been astounded at the almost child-like attitude of mind of some of our chemists who are too ready to sell their services to anybody who has a temporary use for them, irrespective of the underlying motives or purposes.

Some lawyers tell me that they never have the slightest difficulty in hiring chemical experts to defend contradictory opinions. It is quite amazing how some chemists in their eagerness of pleasing their employers will overlook their own ignorance of the most elementary principles of patent law, as well as their superficial acquaintance with the many details of intricate technical questions while not hesitating to furnish cocksure opinions which encourage infringers or industrial pirates to trespass on the rights of intellectual property of others.

Much ruinous patent litigation would be avoided in this country, and invention would be better encouraged if we had more men of the type of some well-known British electrical expert, who never hesitates in court to tell the simple and direct truth, regardless whether it kills or saves the case of his client; his statements are so highly valued and respected that the judges accept them without suspicion, and the same expert is frequently retained by the two opposing parties, whom he serves impartially, and who gladly pay him higher fees than to a mere litigation-acrobat-expert, or a chemical "ambulance-chaser."

EMPLOYERS AND EMPLOYEES

The ethics of our profession have been dealt with by the American Institute of Chemical Engineers, and have been embodied in its recently adopted Code of Ethics, which may furnish a good guide for younger or less experienced chemists. And this leads me to state that many more manufacturers or businessmen would be induced to utilize the services of chemists, if they could feel confident that in so doing they are not putting themselves at the immediate mercy of a stranger, by confiding to him facts or processes which it has cost them many sacrifices of time and money to accumulate, and the undivided knowledge of which, constitutes sometimes one of their most valuable assets. On the other hand, a chemist can hardly be of any service unless his client or employer is just as frank with him as he would be with his lawyer or physician.

However, this mooted point is easily overcome by referring to the Code of Ethics to which I have just alluded, or better by making a preliminary agreement between the chemist and his client or employer, safeguarding the interests of both parties. But in such a case, the compensation to the chemist should be made commensurate to the occasion.

This same principle holds good in the employment of chemists in manufacturing plants, where the chemist is either engaged in research or in a manufacturing capacity. An employer should not expect an intelligent chemist to render him important services without proper compensation, and in as far as the practical value of the work of a chemist can seldom be determined in advance, it will pay the employer to offer special inducements or rewards for initiative; he can well afford to give his chemist some share of the increased profits he has received through his work; to do otherwise, would be narrow-minded, short-sighted, and detrimental to the direct interests of the employer.

The work of a research chemist cannot be performed nor measured like that of a bookkeeper or a laborer; the results of his work are uncertain; delays and obstacles beset him at every turn; sometimes luck plays an important role; but good will, enthusiasm, and persistent endeavor are indispensable factors and these may be encouraged or killed by the attitude of the employer. An employer who is unfair, or who cannot arouse the respect or the enthusiasm of his chemists, cannot get the best there is in them. He must make them feel that if their work turns out well for him, they will get some decent share of compensation. Therefore, a reasonable salary ought to be supplemented by the possibility of a bonus or some share in the profits based on the earnings brought about directly by the work of the chemist.

On the other hand, the chemist must not overlook the financial sacrifices and business-risks assumed by his employer. He should specially bear in mind that knowledge or experience gathered at great cost by his employer, or through expensive factory equipment, or other facilities, have in most cases enabled him to take up his own work at an advanced stage. It would be rather unfair, unless otherwise stated, that a chemist should be allowed during or after his period of employment, to divulge or take advantage of all knowledge or information gathered around the plant in which he is engaged; or patent for his exclusive benefit, any inventions he may make on those particular subjects for which he is engaged, as long as the stimulating ideas themselves have been gathered by the very means put at his disposal by his employer. All these questions should be provided for and embodied in an equitable contract which will necessarily vary with special circumstances. But here again, niggardliness, or too great cunningness of the employer, will hardly pay. Unless his chemist be a fool—and a fool of a chemist is not worth anything—he will lose the good-will and confidence of the very man whose work is primarily dependent on these factors.

Faithful and generous observance of these conditions has brought about the most excellent results in many instances; I know that the contract system, with a salary supplemented by a bonus, or participation in profits in special departments, has been used with great advantage to all concerned, by some of the most successful chemical companies in Continental Europe, and in some of the more progressive American enterprises.

It has been objected that a contract of the kind merely binds the employer who has tangible assets, while in most cases it would be difficult to enforce it against faithless employees. But even then, a clear and well defined contract will prevent many misunderstandings which will crop up in the course of time. It has been my experience that direct dishonesty and faithlessness are merely exceptions among chemists, whatever their other short-comings may be.

THE CHEMIST AS A RESTLESS PROSPECTOR

We know where the work of the chemist begins. We can never tell where it ends, and through what unexpected ramifications it may lead. It is just this fact which adds some zest to the life of the struggling, hard-working chemist, and brings to his work frequently as much excitement as the best of sports; his hopes and disappointments can be compared to those of the restless prospector.

Pasteur, while he was professor at the University of Lille, was consulted by a local alcohol distiller about some irregularities in the fermentation processes. Little did the great French chemist dream, when he tried to solve this purely industrial problem, that by doing so, he was going to establish such an amount of new and unsuspected scientific facts, destined to upset all formerly accepted notions, not merely on fermentation, but on life, disease, contagion and epidemics; that he was about to revolutionize surgery, sanitation and medicine, and create several new departments of medical science; that he was going to save millions of lives, reduce sorrow and misery.

So little were the men of that period prepared for all these stupendous revelations that this great benefactor of the human race had to suffer most from the gibes and violent attacks of some of the best-known men of that very medical profession into which he was going to infuse new life by placing it on a true scientific basis. The history of the stubborn polemics and angry discussions at the French Academy show that, at that time at least, the imagination even of men of science could not expand to the point of perceiving that medicine and surgery were to be remodeled by the hands of a mere chemist.

Notes on Reverberatory Smelting Practice of Nevada Consolidated Copper Co.

(Editorial Correspondence)

Conditions surrounding reverberatory smelting at the plant of the Nevada Consolidated Copper Co., McGill, Nevada, differ somewhat from those at smelters treating copper concentrates from the other large "porphyry" copper properties. While the copper content of the original ore, averaging 1.55 per cent for August, compares favorably with that of similar ores, there is a greater abundance of iron sulphide which lowers the concentration ratio. This results in a low-grade concentrate—7 to 9 per cent copper—and the conversion of a low-grade matte—about 27 per cent copper—and necessitates the treatment of an abnormally large tonnage for a given output of copper. The grade of concentrate fluctuates from day to day with production from different parts of the mine; and as the smelter treats the concentrates practically as fast as produced, there is no opportunity for mixing to secure uniformity of charge. Proper fluxing is effected by varying the feed of lime rock at the roasters in accordance with analyses of current mill production.

Mr. Pomeroy[1] has published the following analyses of charge components and furnace products:

Material	Per cent Cu	Per cent SiO_2	Per cent Fe	Per cent CaO	Per cent Al_2O_3	Per cent S
Concentrates roasted	6.48	28.4	27.0	...	5.2	28.4
Cold secondaries	9.37	19.9	43.4	...	3.4	8.4
Hot converter slag	2.01	27.2	46.2	...	4.5	1.2
Fettling slimes	3.32	65.8	7.3	...	8.3	7.6
Lime rock	...	2.1	0.8	51.1	0.8	...
Roaster flue dust	5.85	40.4	15.2	0.7	6.6	9.2
Reverberatory matte	27.46	0.4	40.8	...	0.5	27.2
Reverberatory slag	0.298	42.2	28.4	9.5	6.8	0.4

Under present conditions, when every department of the plant is being pushed to capacity, the lack of ample facilities for roasting is being felt. With insufficient means for eliminating sulphur, the grade of the resulting reverberatory matte is not as high as might otherwise be obtained, and this, in turn, places an additional burden on the converters.

The roasters, which have six hearths 18 ft. inside diameter, are making a creditable performance, considering that they were originally designed for the treatment of 50 tons each per day. They are now handling nearly twice that amount of charge. The daily average for August was 91 gross tons, consisting of 79 tons of ore and 12 of lime rock. Seventy-five per cent of the sulphur is eliminated, amounting to 15 tons per furnace day. In order to utilize the heat of the roasters as fully as possible in the elimination of sulphur, the practice has been adopted of introducing the lime rock on the fifth hearth, or next to the bottom. Some further changes are now contemplated at the roasting plant that will improve the draft and sulphur elimination, as a result of which it is expected that the grade of reverberatory matte can be raised to about 30 per cent copper.

Crude Oil for Smelting Fuel

Fuel is the main item of cost in reverberatory smelting at McGill. Here the furnaces are oil-fired, using California crude petroleum heated to between 175 and 200 deg. Fahr. There is no probability of a change from this practice to the use of coal dust, notwithstanding the excellent results obtained with the latter fuel elsewhere. A number of factors determine this decision at McGill. In the first place the cost of coal of any grade is high, while fuel oil is obtainable from California at moderate cost. Second, the excellent fuel ratios now obtained with oil, compared with those reported from other plants fired with coal dust, lead the management to believe that coal dust would show no advantage or improvement over oil. And finally, the capital and operating costs of a coal-pulverizing plant are eliminated by the use of oil, which requires no preparation other than heating. Compressed air, of course, is required for either method of firing.

The number of burners to each furnace has been reduced from seven to five, and sometimes only four may be in use. The oil is fed under static pressure of 34 lb. and atomized with air at 40 oz. Combustion is practically perfect. The maximum temperature is developed at the second side door, 21 ft. from the burners, ranging from about 2650 to 3075 deg. Fahr. The furnaces are charged through four holes in the roof, 20 to 25 tons at a time. The side walls are fettled in the usual manner, the openings being piled full of fettling material. Different fettling materials are used at various points for special purposes. Thus converter secondaries are charged along the firing wall or wherever it is desired to sink a heavy material below the slag line to act as a foundation for silicious fettling. Flotation concentrates, which are now being produced in the course of experimental work at the concentrator, are used extensively for fettling.

Recent Furnace Performance

In explanation of the following data, the term "total charge" indicates the sum of the "solid charge" plus converter slag. The "gross fuel ratio," expressed in barrels of oil consumed per ton of charge smelted, gives the total oil consumption. In order to get the "net fuel ratio," a credit must be applied for heat recovery at the waste-heat boilers. This credit is based on water evaporated, and is expressed as a percentage of a factor of 14 lb. water per pound of oil.

For the month of August, 1915, the average tonnage of total charge per furnace day was 645, of which about 15 per cent was hot converter slag. Oil consumption averaged 0.48 bbl. per ton of total charge. Applying a credit of 35 per cent for waste-heat recovery, the net oil ratio was 0.312 bbl. per ton of total charge. Furnace No. 2 had an average daily record of 671 tons and a gross fuel ratio of 0.45 bbl. of oil.

[1]New York meeting A. I. M. E., February, 1915. "Reverberatory Smelting Practice of Nevada Consolidated Copper Company." By R. E. H. Pomeroy, smelter superintendent, McGill, Nev. The supplementary data on furnace operations given in these notes were kindly provided by Mr. Pomeroy during a recent visit at the plant.

On August 31, 1915, furnace No. 2, measuring 18 ft. 10 in. by 132 ft. at the skim-line level, had been in continuous operation for one calendar year, and the campaign was not yet closed. During this period the furnace treated over 240,000 tons of charge, a performance which has encouraged the management to set a new goal of a quarter of a million tons in a single campaign. The exact data on this furnace are given below.

Furnace days	358.3
Total charge, tons	241,053
Solid charge, tons	213,223
Total charge per furnace day, tons	673
Solid charge per furnace day, tons	594
Oil ratio for total charge, bbl	0.565
Oil ratio for solid charge, bbl	0.640

Furnace No. 1 is now on an unfinished campaign, the current record of which follows.

Furnace days	150.7
Total charge, tons	93,618
Solid charge, tons	79,385
Total charge per furnace day, tons	621
Solid charge per furnace day, tons	526
Oil ratio for total charge, bbl	0.482
Oil ratio for solid charge, bbl	0.608

All factors and conditions considered, it is believed that these records are among the best in reverberatory copper smelting. Naturally, they are obtained only by careful study and close attention to detail, discovering the factors that make for high or low efficiency, and augmenting the former and diminishing the latter as much as possible. No small part of the success lies in creating a good organization and maintaining the proper spirit of interest and loyalty in the operating crew.

The Estimation of Aromatic Hydrocarbons in Cracked Petroleum[1]

BY W. F. RITTMAN, T. J. TWOMEY AND G. EGLOFF

In connection with the commercial production of aromatic hydrocarbons from petroleum a necessity has arisen for convenient and reasonably accurate analytical methods. Such methods may have as a basis either chemical or physical differences among the properties of the constituents of the mixtures which are produced by the cracking process. The present communication deals with the application of physical methods to the processes of separation and differentiation. Some experiments have also been performed on the chemical side of the question results of which will be published in a subsequent connection.

The following physical properties are suggested as of possible utility:

1. Solubility.
2. Melting point
3. Boiling point.
4. Specific gravity.
5. Refractive index.
6. Surface tension.
7. Viscosity.
8. "Molecular weights" (effect on boiling point or freezing point when in solution).

Of these properties the first three may permit an actual separation of the constituents of a mixture. The other can serve [at most] only as means of differentiation.

Several possibilities may be eliminated on the basis of previous knowledge. Surface tension is readily influenced by the presence of small quantities of impurities and in the absence of definite knowledge concerning the exact nature of this phenomena, is of little service. "Molecular weights"[2] have been shown to be unreliable even when determined for mixtures which are chemically more homogeneous than those obtained in the present work.

Refractive indices are related closely to specific gravity, and on account of that relation do not need special consideration. Viscosity is not an additive property. In actual fact, information is needed regarding only the first four possibilities of the list.

A consideration of actual conditions reveals the following state of affairs: The cracked petroleum oil is a complex mixture containing a series of aromatic hydrocarbons, of which the most important are benzene, toluene and xylene. "Xylene" represents a mixture of the three isomers, the properties of which are closely related. Higher aromatic hydrocarbons are likewise present and work is at present in progress for the purpose of studying methods for their separation and estimation. There are also present in the mixture considerable quantities of non-aromatic hydrocarbons of various classes and of almost all boiling points. From these facts it appears improbable that the desired separation and estimation may be accomplished through an application of any one property.

A method of separation which suggests itself as particularly attractive is that based on differences in solubility. Unfortunately, however, there are known few, if any, satisfactory differences of this sort. Certain asphalts are dissolved by aromatic and are unattacked by non-aromatic hydrocarbons, and this fact has been utilized for a qualitative test[3] for the former.

The use of liquid sulphur dioxide has many of the characteristics of a differential solubility method, but in the present connection has been classed as a chemical method.

One other solvent which is recommended as offering a satisfactory medium for separation by solubility is dimethyl sulphate. Experiments have been performed to discover the utility of this method when applied in the simple way practicable in the ordinary commercial laboratory.

A second possible method of separation depends upon differences in melting point. An examination of physical chemical tables indicates that benzene[4] freezes at about 5°.5 C., and that all the hydrocarbons which are associated with it in distillation cuts have considerably lower points of solidification. Experiments have been conducted to ascertain whether or not any simple and convenient laboratory method may be based on these differences.

The method of separation through differences in boiling point needs little discussion. That it is possible to separate benzene, toluene and xylene by the method of distillation is indicated by the differences in their boiling points:

Benzene[5], 80°.4.
Toluene[6], 110°.3.
Xylene[7], 138 to 142°.

While, however, the three aromatics may be separated from each other by the process of rectification they cannot be isolated from the aliphatic hydrocarbons which are present in the cracked oil, and which have boiling points approximately the same as those of the benzene, toluene and xylene.

A convenient fact appears in the wide differences

[1]Published with the permission of the Director of the Bureau of Mines.

[2]Rittman & Egloff, J. Ind. Eng. Chem., vol. 7, 582 (1915).

[3]Qualitative Method of Holde. Examination of Hydrocarbon Oils. Holde, Mueller, page 49.
See also Allen's Commercial Organic Analysis, Vol III, page 241.

[4]Lochowieg (M. P. 5° 42), Ber., 21, 2206, 1888. Paterno (M. P. 5° 53), Gozz. Chim., ital., 27, 481, 1897. Young (M. P. 5° 58), Proc. Royal Soc., Dublin, 12, 31, 385, 1910. Richards & Shipley (M. P. 5° 483), *J. A. C. S.*, 36, 1831, 1914.

[5]Kuops, Liebig Ann. 248,175 (1888).

[6]Landolt & Jahn, Z. Phys. Chem. 10, 303 (1902).

[7]Barbier & Rowe, Bull. soc. chim. 3255 (1890); Weegman, Z. Phys. Chem. 2237 (1888).

between the specific gravities of the aromatic hydrocarbons and those of the other constituents of approximately like volatility. Table 1 indicates the wide variation.

Specific gravity may be easily and accurately determined, and through its use is suggested a possible

TABLE I.—SPECIFIC GRAVITY DIFFERENCES BETWEEN PARAFFIN AND AROMATIC HYDROCARBONS HAVING APPROXIMATELY THE SAME BOILING POINTS

	B. P.	Gravity
Paraffin Hydrocarbons		
Dimethyl Pentane[8]	86°	0.711/0°
Diisobutyl[9] (b)	108°.5	0.713/0°
Nonane[10]	131°.5/751 mm.	0.742/12°.4
Aromatic Hydrocarbons		
Benzene[11]	80.4	0.876/20°
Toluene[12]	110.3	0.871/14.7°
Xylene[13] (o)	142°	0.885/14.1°
(m)	139°	0.869/15.7°
(p)	138°	0.866/14.7°

satisfactory method of differentiating compounds which are alike in the property of volatility.

Experimental

SOLUBILITY METHOD—USE OF DIMETHYL SULPHATE

Valenta[14] has stated that aromatic hydrocarbons are soluble in dimethyl sulphate and that open chain hydrocarbons are practically insoluble. This condition, however, he limits to compounds having boiling points between 240 deg. and 300 deg. C.

Since the publication of his results the utility of this reagent has been investigated by various experimenters. Perkins and Harrison[15] subjected it to a number of

TABLE II.—PERCENTAGE SOLUBILITY OF MINERAL OILS IN DIMETHYL SULPHATE

	Per Cent Dissolved	Sp. Gr.	Volume Dimethyl Sulphate Used
Spindle oil	3.2	.....	1.5
Cylinder oil	.....	0.903	1.5
Russian oil	2.3	0.897	1.5
Russian oil	0.0	0.900	1.5
American oil	5.0	0.875	1.5
American oil	1.1	0.903	1.5
Scotch	7.6	0.885	1.5
Galician	7.6	.....	1.5
Petroleum ether	17.2	.....	1.5
Kerosene	3.4	0.798	1.5
Mineral oil, B.P. 160° to 300°	7.2	.....	1.5
	14.4	.....	2.0
Mineral oil, 160° to 300°	12.0	0.803	1.5
Blast furnace oil	36.0	.....	1.5
Blast furnace naphtha	20.5	.....	1.5
Blast furnace burning	14.0	.....	1.5
Shale oil, Pearline	13.0	0.865	1.5
Turpentine, Russian	28.3	.....	1.5
Turpentine, American	29.0	0.915	2.0
Rosin oil*	24.0	.....	1.0
Rosin oil	44.0	.....	2.0

*Valenta states only soluble to a slight extent. Chem. Zeitg. 30, 266, 1906.

trials and found that it dissolved percentages of petroleum hydrocarbons varying from zero up to considerable amounts. Their results are shown in Table No. 2. Table No. 3 illustrates per cent of recovered aromatic hydrocarbons, xylenes, when mixed with varying quantities of paraffin hydrocarbons. Their conclusion is that any method based upon the separation effected by dimethyl sulphate lacks value in the matter of quantitative accuracy, and that occasional good results obtained are due to fortunate accident.

[8]Ladenburg, Liebig Ann., 142,310, 1867.
[9]Kopp, Liebig Ann., 95,336, 1855.
[10]Lemoine, Bull. Soc. Chim., 41,164.
[11]Kuops, Liebig Ann., 248,175, 1888.
[12]Landolt & Jahn, Z. Phys. Chem., 10,303, 1892.
[13]Barbier & Rowe, Bull. Soc. Chim., 3255, 1890; Weegman, Z. Phys. Chem., 2237, 1888.
[14]Chem. Zeitg., 30, 266, 1906.
[15]Analyst, 33, 2, 1908.

TABLE III.—MIXTURE OF VARIOUS PERCENTAGES OF XYLENE AND MINERAL OILS

Oil	Percentage Volume Xylene in Oil	Percentage Volume Absorbed	Percentage Difference	Volume of Dimethyl Sulphate Used
Spindle	43	36	7	1.5
Spindle	58	49	9	1.5
Spindle	43	41	2	2.0
Russian	23	9	14	1.5
Russian	35	21	14	1.5
Russian	33	25	18	1.5
Russian	46	29	17	1.5
Russian	22	8	14	1.5
Russian	46	38	8	2.0
American	51	41	10	1.5
American	27	27	00	2.0
American	36	29	7	2.0
American	51	48	3	2.0
Queens	17	17	0	1.5
Queens	47	37	10	1.5
Kerosene	9.6	12.5	2.9	1.5
Kerosene	50	43	7	2.0
Galician	11	12	1	2.0
Galician	22	16	6	1.5
Galician	48	36	12	1.5
Galician	88	84	4	1.5
Scotch	18	13	5	1.5
Scotch	47	36	11	1.5
American	31	28	3	1.5
American	41	33	8	2.0
Roumanian	28	33	5	2.0
Roumanian	59	61	2	2.0
Roumanian	51	52	1	2.0
Petroleum ether	19	24	5	1.5
Blast furnace oil	51	72	21	2.00
Rose oil	32	54	22	2.00

Chapin[16] also arrived at the conclusion that dimethyl sulphate does not effect a quantitative separation, but believes that under certain conditions the results may be of value. Reeves and Lewis[17] have found the reagent of service and suggest that it may be of value if used in conjunction with a volatilization test. They believe, however, that more data must be accumulated. On the other hand, Sommer[18] has failed by the use of dimethyl sulphate to detect as much as 10 per cent of asphalt in oil.

Church and Weiss[19] have studied the behavior of the reagent under the exact conditions specified by Valenta[20] and find that with coal tar and water gas tar distillates boiling between 240 deg. and 300 deg. C. dimethyl sulphate failed to show indications of non-aromatic constituents when by the sulphonation methods, amounts varying between 1.2 per cent and 6.8 per cent were estimated.

Church and Weiss arrive at the conclusion that the use of the reagent does not attain any degree of accuracy, and that dimethyl sulphate is, in addition, undesirable because it is difficult to obtain in a pure state, is unstable, and on account of its poisonous nature is dangerous to those handling it.

In the present experiments the method of application was as follows: Five cubic centimeters of the sample were measured into a 25 c.c. stoppered and graduated cylinder and 20 c.c. of dimethyl sulphate added. The mixture was shaken for five minutes, heated for fifteen minutes and shaken again.

In no case did any separation occur, even when the mixture treated was known to contain a considerable proportion of non-aromatic constituents. This discrepancy may have been due to any one of the causes indicated above, and it therefore appears that dimethyl sulphate is entirely lacking in utility for the present needs.

FREEZING METHOD

The fact that benzene crystallizes at about 5.5 deg. C. and all other hydrocarbons which might be present with it in a distillation cut about 100 deg.[21] lower led to

[16]Bureau of Animal Industry Circular 167.
[17]*Jour. Ind. Eng. Chem.*, 5, 293, 1913.
[18]Ibid, 2, 5, 1910.
[19]Ibid, 6, 296, 1914.
[20]Loc. cit.
[21]Toluene, M. P.—92.4. Guttman, *J. Chem. Soc.*, 87, 1037, 1905. N Hexane, M. P.—93.5. Richter, Kohlenstofferverbindungen, I, p. 325.

the belief that this properly might be used as the basis of an analytical method. Some experiments were therefore conducted with known mixtures of benzene and a unrefined gasoline of specific gravity of 0.728. These mixtures were treated at three temperatures. Melting ice gave a temperature of zero degrees centrigrade. An ice-salt mixture gave a temperature of — 20 deg. C. A temperature of — 40 deg. C. was obtained by the admixture of carbon dioxide with an excess of acetone in a Dewar flask.

At zero degrees no solidification took place with any of the mixtures, except with the 90 per cent mixture, which gave a recovery of 20 per cent, within the time of a reasonable period of treatment. In all cases the mixture was kept at the required temperature for from fifteen to twenty minutes with constant stirring. Furthermore, inoculation of the solution yielded no different results.

At — 40 deg. results were obtained which show in Table 2.

From these results it appears that benzene crystals tend to include so much mother liquor that the freezing method for the estimation of this constituent is rendered unreliable. It also appears that in the presence of an excess of non-aromatic constituents the benzene crystals may be either prevented from separating out or dissolved as soon as formed. In any event the freezing method seems to have little to recommend it.

DISTILLATION METHOD

The approximate separation of benzene from toluene and toluene from xylene is not necessarily a difficult problem, as there are differences of about 30 deg. C. between the boiling points of each of the adjacent pairs of hydrocarbons. By the use of efficient and convenient still-heads of the Hempel type a satisfactory degree of separation may be attained in three successive distillations, which involves a time consumption of two to two and a half hours for one operator. This procedure, while approximately separating the three aromatics from each other, does not rid them of the non-aromatic constituents with which they are associated.

Table IV.

Percentage Benzene in Mixture	Percentage by Volume Solidifying
90	100
80	100
70	100
60	40
50	25
40, 30, 20 & 10	00

Table V.

Percentage Benzene in Mixture	Percentage by Volume Solidifying
90	100
80	100
70	100
60	100
50	100
40	95
30	40
20	10
10	00

The largely empirical method which has been adopted is as follows: The original cracked oil is distilled and a cut made at 175 deg. C. A portion of this cut is redistilled and divided into three portions at the limits 105 deg., 130 deg., and 160 deg. C. These cuts are subjected to a further fractionation, the temperature limits this time being 95 deg., 105 deg. and 150 deg. C. The cut limit of 150 deg. is fixed by the fact that the distilling flask goes very nearly dry at this point. The figure 95 deg. is midway between the boiling points of benzol and toluol, and 120 deg. very nearly half way between toluene and the lowest boiling of the xylenes.

That the degree of fractionation is sufficient is shown by the results of the following experiment: A specimen of one of the final 95 deg. C. cuts was subjected to a further redistillation, and it was found that 94.3 per cent came over below the original limit. In consideration of the fact that a complex mixture was being distilled this may be considered as a very satisfactory degree of separation.

SPECIFIC GRAVITY

For this accurate determination of the percentages of the three aromatics in their respective distillation cuts by the method of specific gravity it is necessary to know the following three values:

1. The specific gravity of the aromatic constituent.
2. Specific gravity of the non-aromatic constituent.
3. Specific gravity of the cut.

Figures for the pure aromatics are obtainable in the literature.

The following values are given by Holde:[22]

Hydrocarbon	Purity	D 15°/15° C.
Benzene	95% boiling within 0.8°	—0.883 —0.884
Toluene	95% boiling within 0.8°	—0.870 —0.871
Xylene	0% boiling under 136°, 90% below 140°	—0.867 —0.869

Figures for the mixture of unknown composition are obtained from simple laboratory determinations. It is not as easy, however, to arrive at values for the non-aromatics. A scheme that has been used for approximate calculations in another connection (results to be published later) is to use the value obtained for a distillation cut between the same temperature limits obtained from an uncracked oil of the same type as that used in the transformation to aromatic hydrocarbons. This assumes that the properties of the non-aromatic constituents are unchanged by the cracking process. The extent to which this is true yet remains to be proved. Fortunately, however, conditions are such that an approximate knowledge of the gravities of non-aromatic constituents is sufficiently exact for present purposes. On the basis of general knowledge from various sources it has been assumed that the average gravity of these hydrocarbons in the benzene cut is 0.720, in the toluene cut 0.730, and in the xylene cut 0.760. These values are undoubtedly near the truth, but even if they are not their use permits the obtaining of results which are at least as reliable as those derived from analyses by chemical methods.

A specific illustration may serve to show the nature and magnitude of possible errors. The cuts, as obtained by the distillation method, generally ran between 60 per cent and 80 per cent benzene. The figures in Table 6 show the differences obtained by assuming for non-aromatics specific gravity figures respectively of 0.710 and 0.720.

Table VI.

Sp. Gr. (Measured)	Per Cent Benzene on Basis of 0.72 for Non-Aromatics	Per Cent Benzene on Basis of 0.71 for Non-Aromatics
0.816	60	62.5
0.832	70	72.0
0.848	80	81.0

The error, or rather variation, ranges between 1 per cent and 2.5 per cent on this basis. The lower values for benzene were obtained with the higher assumed gravity for the non-aromatic constituents. For the toluene and xylene cuts conditions are similar except

[22] Holde-Mueller, Op. cit., p. 260.

that the possibility of error in assumption is even less, due to the narrower range in boiling point of the cut.

To ascertain definitely the reliability of these assumptions concerning specific gravities an extensive set of supplementary experiments was conducted. First, the gravity results were verified by a series of chemical tests performed by the authors. Present experience has led to a preference for the nitration method for the determination of benzene, this being preceded by a removal of unsaturated open chain compounds. Procedure was as follows:

(*a*) *Removal of Olefines.*

A 100 c.c. sample of the 95 deg. distillation cut is measured into a 500 c.c. separatory funnel. To this was added 100 c.c. of conc. sulphuric acid (sp. gr. 1.84). During the addition of the acid and the subsequent shaking for five minutes the mixture is cooled with ice water. A reddish-brown sludge forms which may readily be separated by centrifuging for fifteen minutes, although it does not settle with long-continued simple standing. The acid-sludge mixture is drawn off and the residual oil subjected to nitration according to the method of Lunge.[23]

(*b*) *Nitration.*

The procedure for nitration is briefly as follows: The sample of about 100 c.c. of oil is placed in a 500 c.c. flask equipped with a dropping funnel and a tube which acts as an air-cooled reflux condenser. Into the oil is run dropwise and with constant shaking a well-cooled mixture of 100 g. of nitric acid (sp. gr. 1.4) and 180 to 200 g. of conc. sulphuric acid (sp. gr. 1.84). The flask is cooled during the addition by immersion in ice water. After the cessation of all tendency toward spontaneous heating of the mixture the flask and its contents are heated for two hours at a temperature of about 60 deg. C. The escape of vapors is prevented by the use of an efficient reflux condenser. After cooling, the contents of the flask are transferred to a separatory funnel, allowed to settle and the lower acid layer drawn off. The latter is diluted with several times its bulk of water, and any oily liquid separating is added to the nitrobenzene.

The crude nitrobenzene is washed three times with water, once with very dilute caustic soda and again with water. It is dried and weighed, then distilled up to 150 deg. and the distillate again treated with a large excess of the nitric-sulphuric acid mixture. Any liquid remaining undissolved in the acid is regarded as nonnitrifiable material.

Experimental Results

Nitration experiments were conducted upon specimens of the 95 deg. cut of such gravities that the benzene content was estimated at from 65 per cent to 99 per cent. Two or three determinations were made for each sample and results obtained which checked with variations of ½ to 1 gram in the quantity of nitrobenzene obtained.

Table VII.

Sp. Gr. of Sample	Per Cent Benzene on Basis of Sp. Gr.	Per Cent Benzene on Basis of Nitration Figures	Per Cent Difference
0.824	65.0	63.6	1.4
0.828	68.1	66.2	1.9
0.840	75.0	72.0	3.0
0.848	80.0	77.2	2.8
0.867	91.9	88.0	3.9
0.872	95.0	92.3	2.7
0.878	98.8	96.0	2.8

Results show in Table 7:

[23]Coal Tar and Ammonium, Lunge, 4 edit. (1909), Vol. II, page 765.

In each determination the per cent of benzene found by the nitration method is lower than that indicated by the specific gravity figures. That the results of the nitration method should be low is indicated by the fact that there are unavoidable errors due to losses in washing and transference, and that there is a possibility of the removal of benzene in the course of the deolefinization with sulphuric acid. Chemically pure benzene cannot be made to yield 100 per cent of the theoretical amount of nitro-product. The specific gravity figures are undoubtedly the more accurate and the assumption of the value 0.720 is hereby justified.

A second check on the reliability of the specific gravity-distillation method was obtained through the results of several analyses made in laboratories which specialize in the examination of hydrocarbon mixtures. These worked independently on samples of a cracked oil and a 200 deg. distillation cut from the same. The latter represented about 42 per cent of the cracked oil.

Results of the analyses show in Table 8.

Table VIII.

Analysis Number	Cracked Oil		Distillation Cut	
	Per Cent Benzene	Per Cent Toluene	Per Cent Benzene	Per Cent Toluene
1	10.50	11.50	29.00	26.25
2	11.68	11.33	23.20	26.20
3	.....	.....	39.91	23.55
4	9.60	6.60	30.20	24.80
5	13.00	10.70	26.20	23.80
Average 1-5	11.19	10.03	29.70	24.92

Analysis No. 1.—The method employed was distillation, followed by deolefinization and redistillation with subsequent determination of aromatics by the sulphonation method. Results show one slight discrepancy in that they do not indicate the same ratio of benzene and toluene in cracked oil and distillation cut derived therefrom.

Analysis No. 2—The oils were distilled and redistilled with efficient fractionating columns and subsequent determinations made by both sulphonation and nitration methods. The latter were given the preference. Results were submitted with the statement that they were probably 1 or 2 per cent too high. Here again there is a discrepancy between cracked oil and distillation cut, and it is in the opposite direction to that noted in analysis No. 1.

The results of both the preceding analyses are probably as reliable as could be obtained by laboratories working in ignorance of the exact conditions under which the cracked oil was produced and distilled.

Analysis No. 3 was made with a single separation by distillation, followed by duplicate determinations by the methods of sulphonation and freezing. The figure for toluene is near that obtained by other laboratories. That for benzene is high, probably because reliance was placed on the results of the method of freezing.

Analysis No. 4 was submitted without statement as to method. Results are in general low, which indicates a reliance on purely chemical methods.

Analysis No. 5 was made by the authors by the method of distillation and specific gravity indicated above. The results are similar to those of analyses No. 1 and No. 2, but have the advantage of agreeing as to the ratio of benzene and toluene in cracked oil and distillation cut.

Summary

The following conclusions have been reached through the results of a series of experiments performed with the degree of care and accuracy generally feasible in commercial laboratories:

1. Solubility methods for the separation and estimation of aromatic compounds in cracked petroleum do not seem to be satisfactory.

2. The freezing method for the determination of benzene yields at best only qualitative results.

3. (*a*) Results approximating those of the best chemical methods may be obtained by the method of separating aromatic hydrocarbons with three successive distillations and determining their percentage in distillation cuts by specific gravity relations.

(*b*) The method of procedure which has seemed most satisfactory on the basis of present experience is as follows:

Seven hundred grams of cracked oil are distilled from a 1 liter distilling flask through a fractionating column whose efficiency is at least as great as that of a 5-in. Hempel column of aluminium beads. Two successive redistillations are conducted, likewise with efficient fractionating columns. For these a 200 gram portion of the 175 deg. cut is taken. For the first redistillation fractions are separated at the temperatures of 105 deg., 130 deg. and 160 deg. For the second the cuts are made at 95 deg., 120 deg. and 150 deg.

Specific gravities are then determined by whatever method seems convenient. Measurements should be accurate to about one part in a thousand. The percentage of aromatics is then calculated from these values on the basis of the following gravity relations in the various cuts:

Temp. of Cut, C.	Sp. Gr. of Aromatic	Sp. Gr. of Non-Aromatic
95°	0.880	0.720
120°	0.871	0.730
150°	0.869	0.760

(*c*) The one assumption upon which this method is based is the gravity value assigned in each case to the non-aromatic constituents of the distillation cut. This need not be known with great accuracy, but with our present knowledge of the mechanism of the cracking process it is desirable occasionally to verify results obtained on the basis of these specific gravities by the application of chemical methods of determination.

Chemical Section of Petroleum Division,
U. S. Bureau of Mines, Pittsburgh, Pa.

Naval Advisory Board

The Naval Advisory Board announced by Secretary Daniels will consist of the following members:

Chairman—Thomas Edison.

American Institute of Electrical Engineers—
Frank Julian Sprague and Benjamin G. Lamme.

American Institute of Mining Engineers—
William L. Saunders and Benjamin B. Thayer.

American Society of Mechanical Engineers—
William LeRoy Emmet and Spencer Miller.

American Society of Civil Engineers—
Andrew M. Hunt and Alfred Craven.

American Chemical Society—
W. R. Whitney and L. H. Baekeland.

American Electrochemical Society—
Joseph W. Richards and Lawrence Addicks.

Inventors' Guild—
Peter Cooper Hewitt and Thomas Robins.

American Society of Aeronautic Engineers—
Henry A. W. Wood and Elmer A. Sperry.

American Society of Automobile Engineers—
Howard F. Coffin and Andrew L. Riker.

American Aeronautical Society—
Mathew B. Sellers and Hudson Maxim.

American Mathematical Society—
Robert S. Woodward and Arthur G. Webster.

Synthetic Phenol and Picric Acid*

BY DR. A. H. NEY

Under normal conditions the world's demand for carbolic acid or phenol is amply covered by the amounts produced by the coal tar industry and the by-products recovery of the coke oven. The recovery of carbolic acid, crude and pure, from the so-called "creosote oils," that is, from afterrun of the light fractions and the forerun of the heavy fractions of the coal-tar distillation and the alkaline washings of the naphthalene fraction, has been developed to a high degree of perfection and refinement in England, the true cradle of the organic chemical industry. Pure carbolic acid (or phenol) has found extensive applications in the arts since its discovery by Runge in 1834, who as the first isolated it from coal tar. The aniline color industry employs it as an important intermediate product; together with its homologues, the cresols, it is extensively used in recent times for the manufacture of synthetic resins, and it is the starting material for salicylic acid and picric acid.

Owing to the extraordinary demand for the latter product in war time, the supply of natural phenol is entirely insufficient; moreover the price of carbolic acid has been subject to considerable market fluctuations, while during the last decade, until the outbreak of the war, the price of benzol has remained remarkably stable. For this reason the synthetic production of phenol from a material always available in practically unlimited quantities has gained considerable importance. Chemical research, of course, has in time produced several ways for the preparation of phenol, synthetically from other materials. All these methods, however, possess no industrial importance, and I refrain from recounting them. They may be found in the literature, the references being contained in Beilstein and other reference books.

Faraday in 1826 prepared naphthalene sulfonic acid by the action of sulfuric acid on the hydrocarbon naphthalene. The technical importance of this operation, called sulfonation, was not realized until half a century later, when Wichelhaus introduced the alkalifusion of aromatic sulfonic acid in the industry, and since that time the stupendous development of the aniline dye industry has found one of its mainstays in the introduction of the hydroxy-group into aromatic hydrocarbons by sulfonation and subsequent alkalifusion. Beta naphthol, one of the most important intermediate products of the coal tar color industry has been produced during the last thirty years in enormous quantities by this method, which is prototype for the synthetic production of phenol. In Germany, synthetic phenol has been produced in insignificant quantities in the last decade of the last century, but when England, during the Boer rebellion, placed an embargo on phenol and a considerable shortage occurred on the continent, the chemical works of F. Raschig in Ludwigshafen engaged in the manufacture of phenol on a large scale and has maintained this whenever the price fluctuation of natural phenol permitted. The chemical works of Hoffmann-La Roche in Basle also produced synthetic phenol for many years and have always been able to compete successfully with the natural product for pharmaceutical purposes.

In this country, previous to the outbreak of the great war, synthetic phenol was never produced, however, not because of our inability, but for economical reasons. Thomas A. Edison, who was the first seriously to feel the consequence of the complete shut-off of the phenol

*A lecture delivered before the National Exhibition of Chemical Industries in New York City on Sept. 24, 1915.

supply, as he uses large quantities in the manufacture of his phonographic disk records, which contain the artificial resin prepared from phenol, as binder and are "faced" with a varnish of the same material, deserves credit for fearless and energetic action in quickly engaging in the manufacture of phenol from benzol. Already early last fall his plant in Silver Lake, N. J., produced synthetic phenol sufficient for his immediate needs, which are considerable. This most creditable achievement is only marred by the fact that the old and well known process was claimed as his own invention, and the appearance of exaggerated and foolish stories in the newspapers was permitted and countenanced.

With the arrival of demand for high explosives from Europe the demand for phenol increased enormously, and gradually other concerns began to prepare for the manufacture of phenol, and all of the many new organizations which were formed on the basis of often fictitious contracts for picric acid for the belligerent governments were compelled to consider the manufacture of phenol. While normally the price of synthetic phenol is about 9 cents per pound, with benzol at about 60 cents per gallon the cost price of synthetic phenol is about 18 cents. But when we consider that the price of picric acid is at present $1.50 to $1.75 for large contracts and that from one pound of phenol about 1¾ pounds of picric acid are obtained, we can see what enormous profits are theoretically involved.

The Manufacture of Synthetic Phenol From Benzol

The synthetic production of phenol from benzol comprises the following steps and operations:

1. Sulfonation of the benzol by strong sulfuric acid.
2. The conversion of the resulting mixture of sulfuric acid and benzol-sulfonic acid into the calcium salts by adding milk of lime to the diluted sulfonation mixture.
3. Separation of the soluble calcium salt of the benzol-sulfonic acid from the gypsum by filtration.
4. Conversion of the calcium salt of the benzol-sulfonic acid into the sodium salt (and separation of the solution of the latter from the precipitated calcium carbonate.)
5. Evaporation (to dryness) of the sodium salt of the benzol-sulfonic acid.
6. Caustic fusion of the sodium salt of the benzol-sulfonic acid.
7. Dissolving the fusion and acidulating the same to liberate the phenol formed and separating the same from the aqueous solution of the salts.
8. Distillation of the crude phenol.

(1) SULFONATION OF THE BENZOL

This operation is carried out in the customary sulfonation kettles, consisting of a cast iron kettle of perhaps 300-350 gal. capacity, having a jacket of any preferred material capable of being heated, either by water, steam or an oil circulating system, to about 80 deg. C. The kettle is in this case preferably provided with bottom discharge. The lid must close tightly, a soft lead casket having been found satisfactory. The lid is provided with man or hand-hole, thermometer pipe, 4-in. opening for running in the charge, an emergency opening, if desired, and connection to a spiral reflux condenser, water cooled, for condensing the benzol vapors. The kettles are elevated to permit gravity discharge into the limeing tanks.

The stirring device is of the greatest importance. Owing to the great difference of the specific gravities of sulfuric acid and benzol, the tendency to separate into two layers and rotate as such is very pronounced, and it is obvious that in that case chemical action is very much impeded. The ordinary horseshoe type of agitator is therefore entirely unsuitable. Two types of agitators have been tried out, and both give about equal satisfaction. One type consists of a pair of ordinary propellers mounted on the shaft, one pair, however, being set conversely to the other; proper speed being 120-180 r.p.m. The other type consists of one complete turn of a broad spiral round the shaft, the whole revolving in a cylindrical case, which is either mounted on the shaft, rotating with same, or is stationary, viz., suspended from the lid or otherwise, a screw conveyor in fact.

For the production of one ton of phenol per day a battery of two kettles is necessary, each kettle being charged and operated twice.

In the cold or slightly warm kettle 410 lb. of sulfuric acid 98 per cent is run in, preferably from a measuring vessel common to all units of the battery. The agitator remains standing. One hundred and fifty-three pounds of benzol are next run in the kettle, the agitator still standing. The operator now closes all openings, excepting that leading to the reflux condensor, and starts the agitator. The temperature soon rises to 62-68 deg. or even higher.

When the thermometer indicates no further rise, heat is admitted to the jacket, and from now until the end of the operation the temperature is maintained as closely as possible to the boiling point of benzol; care, however, must be taken to prevent too energetic ebulition of the benzol which would otherwise be thrown through the condensor.

The sulfonation requires from 5 to 9 hours (in the mean, 7 hours) and is finished when the odor of benzol is practically gone (it never disappears completely) and a sample of the sulfonation, when diluted with many times its volume of water does not separate any drops of benzol. No benzol di-sulfonic acid is formed under these conditions, and the amount of sulfon is negligible. With benzol of good quality and at least partially freed from thiophene, the color of the sulfonation mixture is light straw yellow; on cooling, benzol-sulfonic acid separates in fair quantities, occasionally in crystalline form.

(2) CONVERSION INTO CALCIUM SALT

After completed sulfonation, the resulting mixture of sulfonic acid and sulfuric acid is run into about an equal volume of water contained in the limeing tank. The limeing tank may or may not contain a certain amount of milk of lime or calcium carbonate paste (from the soda tanks).

The limeing tanks (two being necessary for the quantities assumed above, but will suffice for a much larger production) are wooden tanks, preferably, but not absolutely necessarily, lead-lined, with powerful wooden agitators of the "gate" type, all iron parts protected and having a lead steam coil or an open steam pipe. The capacity of each is 1200 gal.; 4-in. bottom outlet, flanged and "flush" inside, proper draining being assured by a slight tilt. Bottom outlet connected to filter press pump (or Montejus if used, which is not advisable).

The milk of lime is prepared in a suitable vessel, for instance a sheet-iron cylindrical tank with iron stirrer and a perforated cagelike basket, removable, in which the lime is placed. Suitable capacity 500 to 600 gal. A straining device should be attached to the outlet.

Suitable proportions for the milk of lime: 1 lb. of burned lime for 0.6-0.75 gal. of water.

The operation of limeing is carried out as follows: Milk of lime is run into the diluted sulfonation mixture, the latter being hot due to the hydration heat of the acid. Steam is turned into the coil when the milk

of lime begins to run in. The milk of lime is added just short of the point of alkalinity, viz., until all sulfuric acid and the largest part of sulfonic acid is neutralized; then sufficient calcium carbonate (chalk or from the soda tanks) is added to neutralize completely. The content has now begun to boil and is maintained boiling for about 20 to 30 min. If it should become too thick, a little water may be added. (Very little water is necessary to thin the mass.) The steam is then turned off and cold water equal to about 1½ volumes of the original volume of the sulfonation mixture is run in.

All these precautions serve the purpose of obtaining the gypsum precipitate in a form permitting rapid filtration and complete washing out of the press cakes with the least volume of water.

(3) SEPARATION OF SOLUBLE CALCIUM SALT FROM GYPSUM

Two filter presses are desirable, but one may do. The filter press with washing device made by Shriver & Co., Harrison, N. J., is probably the best, but when ordering, it should be insisted that two washing inlets, one at the bottom and one at the top of the plate are provided (which is done without extra charge). Open discharge! The lower washing holes should be worked first. Filter presses are best raised on a platform high enough to permit a dumping cart to be driven under it, into which the gypsum cakes are dropped through a chute.

The contents of the limeing tube are pumped into the press at a temperature of about 60 deg. C. and the filtrate collected in the soda tubs. The cakes are washed, by means of the washing attachments, with hot water, the first washing being added to the filtrate while the last wash water may be turned back into the limeing tub in place of pure water for diluting the sulfonation mixture. The amount of wash water necessary depends largely upon the state and form of the gypsum precipitate, that is, if the same has been properly prepared and treated, comparatively little washing will be required, while, on the other hand, if it has been allowed to become slimy, it is very difficult to completely remove the calcium benzol sulfonate from it. The economy of the process depends to a large extent on this factor. Generally speaking the volume of the solution should not be increased more than 50 per cent by the washing operation.

(4) CONVERSION OF CALCIUM SALT INTO SODIUM SALT

The filtrate and wash waters are run by gravity from the troughs of the filter presses into a wooden tub. Two are advisable, of a capacity of 1500 gal. They need not have a stirring device, but preferably have a light one, or may be agitated by air or even by hand. They may have a closed steam coil of good size, in order to evaporate while filling and to boil, which is necessary in order to obtain the calcium carbonate in the proper crystalline form. Soda ash (dry) is added until all calcium is precipitated, which point is recognized when further addition fails to produce more precipitate and by the slight alkaline reaction. No excess of soda should be allowed.

The calcium carbonate is allowed to settle, and the supernatant clear liquid is fed to the evaporator. After the layer of calcium carbonate has increased, say after three or four conversions, it is washed once with water and then withdrawn and used for neutralizing the sulfonation mixture.

(5) EVAPORATION

Evaporation of the sodium salt is obviously carried out most economically in a multiple-effect vacuum evaporator and the drying of the salt in a vacuum oven. However, the temporary nature of the proposition does not always warrant the large investment for installing this apparatus, and any means for evaporation and drying, such as tanks with steam coils for concentration and jacketed shallow pans for drying may be employed.

The dry sodium salt represents a dazzling white finely crystalline mass, which, for the fusion, should be pulverized to a coarse powder, any means to that end being suitable.

The yield of the sodium salt should be practically theoretical, any losses being mechanical and most probably due to incomplete washing of the gypsum cakes.

(6) CAUSTIC FUSION OF THE SODIUM SALT

The caustic fusion is carried out in open cast-iron round-bottom kettles, of about 300 gal. capacity, having an iron stirrer of the horseshoe type, which should as closely as possible approach the sides and bottom of the kettle.

Two fusion kettles are preferably set in brick, arch construction or sheet steel protector to prevent direct contact with the flame.

Heating means, preferably: Schutte & Koerting (Philadelphia) gravity oil burner, size ¼ in.

The kettle is charged with 480 lb. of caustic soda and 30 to 50 lb. water added, which facilitates the melting of the soda. The temperature is raised to 270 deg. C., and then 600 lb. of dry pulverized sodium salt of the benzol sulfonic acid are shoveled in. The temperature should not be permitted to fall, but should, during the throwing in of the sodium salt, rise, so that when all of the latter is in, about 300 deg. C. has been reached. This can be readily done by increasing the flow of the oil of the burner and by regulating the speed with which the salt is added. When all has been added the temperature of the fusion is raised to about 315 deg., whereupon the heat is turned off. The temperature rises a little further but should never exceed 330 deg. However, observation of the temperature is not very essential, as with a little practice the progress, etc., of the fusion can readily be observed and followed by the appearance of the same. A description of these visual indications, however, would help but little, and experience and a few trials in the laboratory will quickly enable the supervising chemist to determine the correct conditions. In general the fusion is completed, when all sodium salt has gone into solution, and the melt becomes thin. No separation in two layers takes place with the above proportions.

(7) DISSOLVING THE FUSION AND ACIDULATION WITH LIBERATION OF PHENOL

When still hot and liquid, the melt is ladled in shallow iron pans or trays and broken up after having solidified and cooled. A crusher might suitably be employed. The workingmen must be provided with rubber gloves and goggles and should be advised to protect their clothing with pieces of sacking. Clogs or wooden shoes, such as worn by the Lancashire mill hands, are also recommended.

The broken-up fusion cakes are now dissolved in water, two parts of water to one part of fusion. The best apparatus for this operation is a sheet-iron cylindrical tank with conical bottom, similar to a benzol washer; it need not be lead-lined as, in contradistinction to the separation of tar-phenol from the alkaline solution by mineral acids, no danger of over-acidulation exists, as acid is only added until bisulphite has been formed. The tank may be open, but should be provided with a hood.

A perforated false bottom, preferably arranged that it can be lowered and raised and entirely removed, should be provided in the tank, and agitation is prob-

ably best provided by air. A lead-pipe with perforated coil, a little above the conical end, serves for running in the acid, and the usual arrangement for withdrawing the liquid at the bottom and at different levels should be provided.

When the cakes are dissolved diluted sulfuric acid from a lead-lined storage vessel is run in until the beginning of copious evolution of sulfurous acid indicates the beginning of the decomposition of the bisulphite. Five thousand pounds of cakes require about 2500 lbs. of sulfuric acid 100 per cent in form of 40 deg. Be. The contents of the tank are now allowed to stand, the aqueous solution containing sodium sulphate and sodium bisulphite is subsequently withdrawn at the bottom, and the phenol freed from sulfurous acid by vigorously blowing air through it for some time.

(8) DISTILLATION OF CRUDE PHENOL

The resulting crude phenol is now distilled from a phenol still and gives, after removal of the forerun, pure crystalline phenol of the highest melting point.

The yield obtained should be one pound of phenol for one pound of benzol.

The synthetic phenol thus prepared possesses frequently a very disagreeable odor characteristic to organic sulfur compounds. Whether this odor is due to the presence of thiophene in the benzol or to compounds formed by the reducing action of the iron in the fusion kettle (or possibly sulfonation kettles) on the sulfuric acid or sulfites, the writer expresses no opinion. This odor, however, can be readily and completely removed by digesting the crude or distilled phenol with common wood charcoal or still better animal charcoal, or distilling it over the same.

Traces of diphenol (dioxy-diphenyl) appear in the after run.

As in all similar cases, when an old established method suddenly obtains greater importance than was the case before, inventors, real and otherwise, have become active. In the case of phenol no tangible result has been obtained. All methods suggested as "short-cuts" in the sulphonation and fusion phases of the process have proven futile. Of course, modifications of the different steps are always possible. So it is, for instance, possible to sulfonate benzol with fuming sulfuric acid of various anhydride contents, but it is then necessary to keep the temperature of the reacting mixture well below 50 deg. as otherwise considerable amounts of disulfonic acids are formed increasing, of course, with the concentration of the anhydride.

Another "invention" often submitted by would-be "phenol experts" is the direct production of the sodium salt of the benzol sulfonic acid by treating the sulfonate with solutions of common salt. This "invention" is based on the practice followed by certain beta naphthol manufacturers, but is unrational because of mechanical difficulties occasioned by the necessity of filtering strongly acid solutions. Furthermore, the "salt" thus obtained contains large amounts of glauber salt, which are a nuisance in the subsequent fusion and require the use of larger proportions of caustic soda. The suggestion centering in directly neutralizing the sulfation and digesting the mess with caustic is too ridiculous to be considered seriously, and only demonstrates the deplorable ignorance in such matters of those who advance it.

Chlorbenzol is a fairly readily accessible, cheap material, especially if use is made in its manufacture of the chlorine produced by the electrolytic alkali manufacture. The chlorine atom in aromatic compounds can be replaced more or less readily by the hydroxy-group by digesting the chlorinated compound with alkalies. When more substituents are contained in the kernel, especially negative ones, the chlorine atom can be replaced very readily, but chlorbenzol is very inert as regard to this reaction and very high temperature and dilute solutions of caustic soda are necessary to perform satisfactorily this conversion. For this reason, which necessitates the use of autoclaves for very high pressure and large volume, the industrial application of this elegant short method for preparing synthetic phenol is out of question.

The Manufacture of Picric Acid

Picric acid is the tri-nitro derivative of phenol, the product of an exhaustive nitration of phenol, many of its derivatives and to some extent of many organic substances.

It presents pale yellow crystalline leaflets of exceedingly acrid taste soluble to about 1 per cent in cold water, more readily in hot water, easily in ether, alcohol and the usual organic solvents. F. P. 122.5. Ignited it burns, without explosion; detonated by fulminates (Ag or Hg) or guncotton it explodes and is one of the brisantest explosives. The salts are very explosive and also a detonator for free picric acid. Specific gravity of fused picric acid is 1.64.

The technical production of picric acid is to-day carried out by two distinct processes:

1. The first and oldest method, which even to-day is employed almost exclusively, consists in nitrating the phenol sulfonic acid obtained by treating phenol with concentrated H_2SO_4 at about 100 to 110 deg. until the odor of phenol has disappeared and the reaction product is completely soluble in water, with an excess of nitric acid, preferably in the presence of an excess of sulfuric acid.

2. The second and more modern method employs as starting material chlorbenzol, which is dinitrated to dinitro-chlorbenzol; this product is separated from the spent nitrating mixture, the chlorine atom replaced by the hydroxyl by heating with caustic soda, and the resulting dinitro-phenol is nitrated.

The possibility of a third commercial method for the production of picric acid is suggested by an old publication by Hepp., *Ann.*, 215, 344 (1882), who claims to have obtained, with an excellent yield, picric acid by oxydizing trinitrobenzol in alkaline solution with potassium ferric cyanide, the possibility of the use of other mild oxydizing agents being implied.

In view of the difficulty in obtaining trinitrobenzol with anything like a satisfactory yield, the commercial feasibility of such procedure, is open to grave doubt, although the writer has private information that a small plant is at the present time producing picric acid to some extent by a process purported to be based upon this method, literature on trinitrobenzol, Kekule, *Ann.* 137, 167; Salkowski, Rehs, *Ber.*, 7, 371; Hepp. *Ann.*, 165, 18.

The chemical and technical literature contains many suggestions and several descriptions for the manufacture of picric acid, all of them, however, being obsolete. Chemically, the preparation of picric acid is very simple and easy and, as a matter of fact, it would seem almost impossible for anyone placing phenol and nitric acid together, in some form and manner, not to obtain picric acid. Technically, however, the manufacture involves several difficult problems, mainly due to the fact that the handling of straight nitric acid is a difficult and dangerous operation precluding the use of materials for receptacles, etc., usually employed in the chemical industry and the somewhat exaggerated fear of contaminating by inorganic salts, detrimental to the stability of the product. The drying and pulverizing of

the material is a very dangerous operation, which, however, is now seldom required in chemical factories, the ordnance works usually requiring delivery of the wet crystals with a moisture content of approximately 20 per cent.

The manufacture of picric acid is carried out as follows:

A large sulfonation kettle of the usual construction, preferably lead-lined, with steam jacket, bottom discharge and agitator, is charged with one part phenol and four parts sulfuric acid, 98 per cent. The mixture is heated under agitation until a sample appears completely sulfonate, that is, soluble in H_2O without turbidity and the complete disappearance of the phenol odor. The content of the sulfonation kettle is now divided into the nitrators which are receptacles, suspended in a space adapted to have hot or cold water circulated therein. To the content of each kettle an equal part of sulfuric acid is added, and after reducing the temperature to below 20 deg. the nitrating acid is run in. The nitrating acid is preferably the usual mixture of equal parts of HNO_3 (40 deg.) and H_2SO_4, but any other proportion is equally suitable. Instead of three molecules required by the theory, four molecules of HNO_3 are added, the temperature being kept below 40 deg., while the first 30 to 40 per cent nitric acid is run in and then gradually increased to 70 or 80 deg., hot water being circulated toward the end of the operation and one to two hours afterward. Proper ventilation must be provided. Air may be blown through the nitrators before removing their content in order to remove the nitrous gases formed.

The content is now removed into an acid-proof, nonmetallic receptacle and diluted with water, about equal volumes having been found to give the best results. After cooling, the picric acid, which separates usually in large crystals, is placed on filtering means, "nutches" or centrifuges, and washed. The formation of too large crystals and "caking" should be prevented. It is usually of sufficient purity for any requirements. To obtain it still purer it may be fused in steam-jacketed enamelled kettle, from which it is run, if desired, through a sieve of platinum or gold, into a wooden tank with water. It is then filtered again. The method suggested in the literature of dissolving in alkali and again precipitating is unrational and dangerous and has never been practised by manufacturers.

The material from which the nitrators are made may be cast-iron, if the strength of the acid is always kept above 82-85 per cent, otherwise earthenware or enamel receptacles are indispensable. After the nitration the mixture is diluted, and for all final operations, contact with metals, other than precious, must be avoided. Coatings of a pure asphaltum varnish have given satisfaction. Proper agitation devices and ready means for discharging the nitrators and filling the same open a wide field for the ingenuity of the construction engineer.

The largest manufacturers of picric acid in the world (Hauff in Fuerbach) use an interesting and highly efficient filtering device. It consists of a filtering box or "nutch," with vacuum below and above, and is adapted to be used as both filter and dryer. The crude picric acid is placed on the filtering surface (a porous stone plate) and suction is applied. After the bulk of the adhering waste acid has been removed, alcohol is sprayed on the material and received in a separate container, from which it is at once rectified and recovered. The filter box is then covered with a specially constructed lid and vacuum applied; the drying proceeds very rapidly and the resulting product is very pure, due to the fact that it has been washed with alcohol, which is an excellent solvent for the resinous products, always formed during high nitration.

First National Exposition of Chemical Industries

The National Exposition of Chemical Industries held in the Grand Central Palace, New York, from Monday to Saturday, Sept. 20 to 25, 1915, was a real great success, even greater than its promoters and most sanguinic well-wishers could have hoped for. Like every exposition, it was a little slow in starting, but by Monday night all the exhibits were well in place, and it was then evident that in spite of being the first exposition of its kind held in the country it was a surprisingly finished and thoroughly representative affair. It is true manufacturers in a few fields, such as chemical stone-ware, were absent, but these were exceptions which only emphasized still more the fact that otherwise the exhibition was truly representative of the industry. The exposition is planned as an annual affair, and the surprising success of the first trial promises even greater successes for the future.

The idea of this exposition originated with two American chemists, Mr. Adrian Nagelvoort and Mr. Charles F. Roth, to whom a great deal of credit is due not only for the origination of the idea but for the perseverance, energy and good common sense with which they made a reality of their idea. They formed an advisory committee, consisting of Messrs. Raymond F. Bacon, H. B. Faber, Charles H. Herty, Arthur D. Little, Wm. Cooper Proctor, E. F. Roeber, George D. Rosengarten, T. B. Wagner and Utley Wedge. Associated with Messrs. Roth and Nagelvoort in the management of the exposition was the International Exposition Company, with Mr. F. W. Payne at the head, whose experience gained in the past in managing fifty large expositions contributed greatly to the success of the present exposition and to the satisfaction of every exhibitor.

The attendance was excellent and high-class in that chemical engineers, managers and superintendents, in general, men with buying power, were present, many of them from out-of-town places and from quite distant states. In honor of the visiting chemists the Chemists' Club held a smoker on Thursday night with vaudeville entertainment; it was a well attended and greatly enjoyed affair.

The general public was also greatly attracted by the exposition; on most of the evenings the show was quite crowded. The average daily attendance was quite a little over 10,000. It may thus be hoped that the exposition has promoted a better understanding by the general public as to what the chemical industries are and stand for. Certainly never before in the history of the world have the New York daily papers shown as much interest in chemistry as during the exposition week.

The adjoining illustrations will give an idea of the attractiveness and comprehensiveness of the exhibition; more details will be found in the concise summary of the different exhibits. We will finally give a review of the numerous meetings and lectures held in connection with the exposition—some of the papers presented are given in the present issue, while more had to be reserved for publication in later issues.

Finally great credit is due to the Bureau of Commercial Economics of Washington, D. C., which had arranged a very interesting moving-picture program on many chemical, metallurgical and industrial subjects, the films varying from day to day.

A concise summary of the exhibits arranged in alphabetical order of the names of the exhibiting companies follows:

Abbe Engineering Co., New York City, exhibited small jar or ball mills in actual operation and also showed a small size of their improved "Max" mill which has a vertical shaft, designed to reduce vibration. Mr. Henry Kleinfeld was in charge.

American Bitumastic Enamels Company, New York City, showed diagrams of the lock gates of the Panama Canal which were treated with their enamel after two years' test with various materials. The enamel has an asphalt base. Messrs. Sealey, Kerns and Ellis were in charge.

American Chemical Society exhibited publications and charts showing the growth in membership during the last few years. Also booth for entertainment of visitors.

American Electrochemical Society:—Pictures of pioneers in electrochemistry and electrometallurgy and also a large portrait of Robert Hare. Historic electric lamp exhibits, an exhibit showing the development of the tungsten lamp; argon-filled lamps, Cooper-Hewitt lamps. Various fine samples of electrochemical products from Niagara Falls. This was undoubtedly the most interesting Society booth at the show. Dr. Doremus, Mr. Bowman and Mr. Muir were responsible for the exhibit.

American Hard Rubber Company, New York:—Acid pumps, buckets, bottles, piping and various other utensils all made of hard rubber. Messrs. F. R. Greuse and E. Johnson were in charge.

American Institute of Chemical Engineers had a booth for entertainment of visitors.

American Paper and Pulp Association, New York City, showed photographs of woods and pulps made from them. This exhibit was loaned by Joseph H. Wallace & Co. of New York.

American Transformer Company, Newark, N. J., had an exhibit in conjunction with that of the Research Corporation, they having supplied the 100,000-volt transformer for the demonstration of the Cottrell electrical precipitation process. Mr. W. F. Hubley was in charge.

Ault & Wiborg, Cincinnati, Ohio, manufacturers of printing ink.

Automatic Weighing Machine Company, Newark, N. J., showed very instructive photographs of their automatic weighing and sealing machines. Messrs. H. D. Bowman and J. B. Mockridge were in charge.

J. T. Baker Chemical Company, Phillipsburg, N. J., had an attractive exhibit of Baker's analyzed chemicals neatly arranged in show cases.

Beach-Russ Company, New York City:—Small sizes of their rotary vacuum pumps and pressure blowers in operation. Their compound dry vacuum pump is guaranteed to produce a vacuum within 1/10 in. of barometer. Messrs. H. C. Russ and J. Buckley were in charge.

Christian Becker, Inc., New York City:—Exhibition of analytical balances. The feature of this exhibit was their new chain balance which weighs without weights, by having a gold chain fastened to the lever arm, the other end of which is raised or lowered to give different weights which are read on a scale, provided with vernier. Readings are accurate to 1/10 of a milligram. Messrs. C. G. Machilas and W. C. Symington were in charge.

W. Beckers Aniline and Chemical Works, Brooklyn, N. Y.:—A very neat exhibit of American made aniline and alizarine colors. The exhibit showed coal as a raw product, then the intermediate products, and finally the finished colors and the dyeing solutions. Messrs. Gustav Drobegg and Cillessen were in charge.

Benzol Products Company, New York City:—An interesting exhibit of coal tar products, including benzol, nitrobenzol, aniline oil, aniline salt, and oxide of iron as a by-product. Mr. J. R. de la Torre Bueno was in charge.

Bethlehem Foundry & Machine Company, Bethlehem Pa.:—A fine tantiron exhibit. A comparative corrosion test was in process with nitric acid dropping on a small piece of "tantiron" and then on ordinary cast iron. A new piece of ordinary cast iron was used each day and the same piece of tantiron was used all the time. The superiority of tantiron with respect to resistivity to corrosion was evident. Messrs. Lehman, Wilbur, A. H. Stevens and Ettle were in charge.

Brown Instrument Co., Philadelphia, Pa., exhibited their electric pyrometers, stationary and portable, also recording electric pyrometers. Messrs. Goheen, Andrews and Printz were in charge.

Buffalo Foundry & Machine Company, Buffalo, N. Y.:—This was one of the most attractive exhibits and occupied the whole back wall of the Exposition Hall. Numerous colored plates, lit up from the inside, showed various castings made by this concern. These were on the rail surrounding the booth. In the booth were many large castings, including a large reducer for aniline work, a caustic pot, crystallizing pan, condenser and cooler bodies for nitric acid, vacuum dryer and vacuum shelf dryer, and dry vacuum pump for pumping within 1/20 in. of barometer. A test was conducted showing the insolubility of "Buflokast" iron in various hot acids, compared with the solubility of common iron. Great surprise was shown by many people at the very large and varied line of work in chemical industries, as illustrated by this exhibit. Messrs. H. D. Miles, E. G. Rippel, E. G. Sleeper and H. B. Underwood were in charge.

Celluloid Zapon Co., New York City:—Lacquer enamels and lacquer, nitro-cellulose and a complete display of different materials treated by "Zapon." Mr. N. E. Dabolt was in charge.

Chemical Catalog Company, New York, N. Y., showed a dummy illustrating the nature of their catalog of chemical apparatus which will appear about the middle of 1916. Mr. R. R. Johnston was in charge.

The Chemists Club, New York City, had on exhibit a series of old photographs and prints of famous chemists, which attracted considerable attention.

Cinnakol Chemical Sales, Bayonne, N. J.:—Samples of their Cinnakol disinfectant, which is non-poisonous and soluble in water.

Detroit Range Boiler Co., Detroit, Mich.:—The Perfect metal bilge barrels on exhibit by this company attracted considerable attention as they have removable heads which can be made liquid tight to conform to I. C. E. specifications. They also exhibited 110-gal. drums which they made for customers who could not get them from Europe. Mr. W. B. Goddard was in charge.

J. P. Devine & Company, Buffalo, N. Y., exhibited one of their vacuum pumps and other apparatus and machinery of their design for the chemical industries. Also a very interesting exhibit showing the quantities of raw material required to produce one pound of phenol crystals from pure benzol in a process installed by them on a large scale. Messrs. F. H. Mason, Charles Devine and R. D. Kehoe were in charge of the exhibit.

Dorr Cyanide Machinery Company, Denver, Col.:—Very instructive working models of the Dorr classifier, agitator and thickener; also a complete working model of their recent continuous causticising apparatus in which demonstrations were given of the manufacture of caustic soda from soda ash and lime, applying the principle of continuous counter-current decantation (see our issue of August, 1915 p. 514). Messrs. J. V. N. Dorr, Noel Cunningham, H. N. Spicer, R. W. Shafor and L. B. Donaldson were in charge.

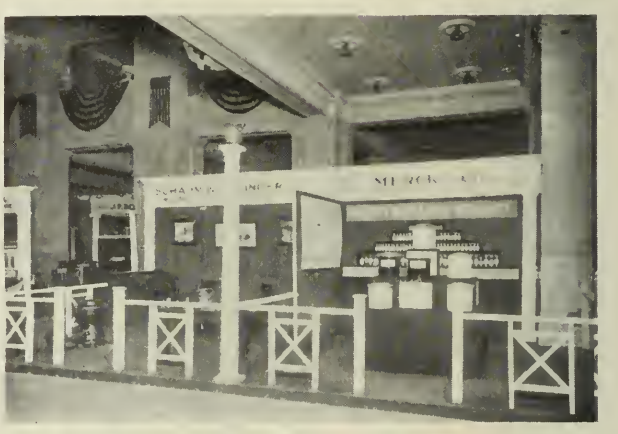
Driver-Harris Wire Company, Harrison, N. J., showed tests on their "nichrome" resistor wire, passing an electric current through of sufficient strength to heat the wire to bright redness in open air, the wire retaining its stability. They also had on exhibit a basket which had been immersed in fused potassium cyanide for eight months (steel hardening process), remaining unaffected. Messrs. Tracy, Bensel, Hart and Henderson were in charge.

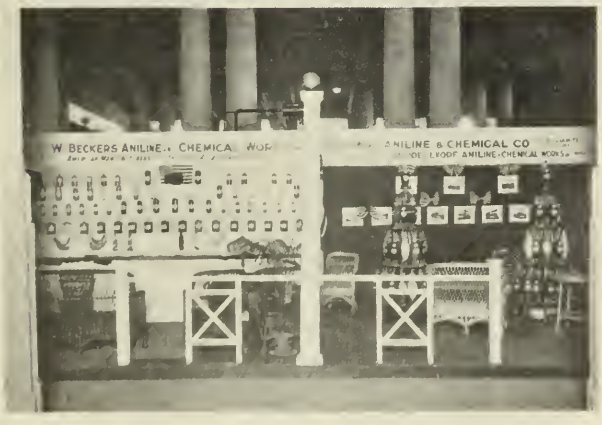
DuPont Chemical Company, New York City (owned by Dupont Powder Co.) showed samples of their various products, among which were benzol, pyroxylin or soluble cotton, commercial amyl acetate. Their various split leather solutions were shown by samples of rough split leather. An exhibit of Fabrikoid was also included. Mr. R. L. Vilas was in charge.

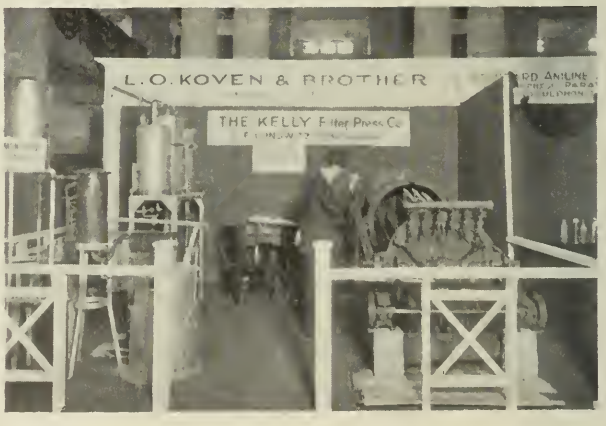
Duriron Castings Company, New York City, exhibited nitric and sulphuric acid condensers; a sulphuric acid concentrator for making 66 deg. Be acid from chamber acid; solid "Duriron" valves and a new 4-in. x 8-in. acid pump used largely for filter press work. Messrs. J. R. Pitman, I. D. Horton and P. D. Schenck were in charge.

Thomas A. Edison, Orange, N. J.:—Benzol, toluol, xylol, and numerous other products. A motor truck size of his new alkaline battery showing the nickel flake, nickel hydroxide, and iron oxide attracted considerable attention. Mr. W. Mallory was in charge.

Eimer & Amend, New York City, exhibited a great many of their laboratory supplies, among which were the Barnstead automatic water still, hydraulic hardness testing machine; "Eanda" American flasks and beakers, and porcelain ware and the Fleming absorption tube. A source of particular interest was found in the new "High-Temp" electric







Exhibits at First National Exposition of Chemical Industries

New York City, September 20 to 25, 1915

furnace manufactured by the Electric Heating Apparatus Co., which was in actual operation. Mr. E. Child was in charge of the booth and Mr. Smalley demonstrated the furnace.

Elyria Enameled Products Co., Elyria, Ohio, exhibited four enameled kettles, illustrative of their line of seamless, one-piece, acid and alkali resistant chemical apparatus. Messrs. William E. Gray, vice-president, J. O. K. White, and E. P. Poste were in charge.

Charles Engelhard, New York City, exhibited the Heraeus Le Chatelier pyrometers for temperature measurements up to 1600 deg. C. This exhibit was in conjunction with the Hanovia Chemical Co. of Newark, N. J. Mr. R. A. Newcomb was in charge.

Fairview Fluorspar & Lead Co., Golconda, Ill., exhibited large blocks of fluorspar, lead ore (galena) and gravel and ground fluorspar.

Foote Mineral Company, Philadelphia, Pa.:—Exhibit of unusual ores, including zirconia ore. Refractory bricks, pure zirconia oxide, silicate, zirkite cement, all made from zirconia ore formed an important part of their display. Mr. H. C. Meyer was in charge.

Geissinger Regulator Company, New York City:—Demonstration of the Geissinger industrial temperature-control system for all classes of temperature-control work, such as conveyor type ovens, large flue dampers in superheaters, dryers, etc. This exhibit was in connection with that of Gerdes & Co.

General Bakelite Company, New York City:—Various products made from this material, showing its wide range of applicability. Included in this exhibit were Weston galvanometers, general molded insulation apparatus, high tension molding for automobile work, some beautiful parasol handles, and cane handles, fountain pens and billiard balls which are more elastic and less resistant to damp weather than ivory. The exhibit was in charge of Mr. H. S. May.

General Chemical Co., New York:—Demonstrations of the baking qualities of their new baking powder "Ryzon," which they have recently placed on the market. Mrs. E. J. Martin was in charge.

Gerdes & Company, New York City, showed their hygienic ventilating apparatus, gears, castings and the Hopes pyramid grate, for improved fuel economy in both natural and forced draft. Mr. Theodore R. N. Gerdes was in charge.

Glens Falls Machine Works, Glens Falls, N. Y., exhibited the Tromblee & Paull rotary sulphur burner, of which they are sole manufacturers. Mr. Hall was in charge of the exhibit.

Emil Greiner Company, New York City, exhibited glassware and miscellaneous laboratory supplies. A feature of their exhibit which attracted attention was a "day-light arc lamp." A filtering glass is placed below a concealed source of light so that the different colors pass through in the correct proportion of daylight spectrum; for color and paint plants, dyeing works and in general for purposes where exact color matching is important.

Hanovia Chemical Co., Newark, N. J.:—Showed Heraeus quartz glass, long distance thermometers, Heraeus pure platinum laboratory furnaces, for temperatures up to 1400 deg. C. and Heraeus transparent quartz glass chemical apparatus. Mr. S. W. Robinson was in charge.

Hardinge Conical Mill Company, New York City:—Complete working model of the Hardinge Mill with glass arranged so that the inside working could be seen. This is a continuous feed and discharge grinding machine. Mr. R. Clark was in charge.

Heller & Merz Company, Newark, N. J.:—Aniline colors, also Bleachette laundry blue and Alderney butter color. Mr. W. J. Robertson was in charge.

Huff Electrostatic Separator Co., Boston, Mass.:—Small working model of the Huff separator which uses 12 to 28,000 volts on ore separation, and a small model of the Plumb pneumatic jig for ore separation. These are both dry processes. Mr. H. P. Johnson was in charge.

F. C. Huyck & Sons, Albany, N. Y.:—Samples of their woven woolen filter cloths. Mr. J. C. Standish was in charge.

International Filtration Corporation, New York City, showed a rotary continuous vacuum filter and their movable leaf or cell type vacuum filter. This consisted of three tanks with an overhead travelling set of filter plates provided with suction. This set of plates could be transferred from one tank to the other for washing after forming the cake in the first tank. Messrs. Dickey, Wheat, Faber and Crosby were in charge.

International Instrument Company, Cambridge, Mass.:—Shaking machine for small bottles, and a complete laboratory centrifugal on exhibit. Mr. Arthur Kendrick was in charge.

Kieselguhr Company of America of Los Angeles and New York City, showed their "sil-o-cel" bricks, and powder made of pulverized celite, and gave a demonstration of the heat withstanding qualities by applying a blast lamp directly to a "sil-o-cel" brick. Messrs. D. S. Collins and P. A. Boeck were in charge.

Lead-Lined Iron Pipe Company, Wakefield, Mass., exhibited valves and pipe fittings, all lead-lined; a feature of their exhibit was a sample piece of 16-in. lead-lined iron pipe furnished by the Chile Copper Company, Antofogasta. Mr. T. H. DuBois was in charge.

Lenz & Naumann, New York City:—General laboratory supplies, including the Riché adiabatic calorimeter, Link's patented water purifier. Tirrell gas making machine for making gas from kerosene, Lenzmann micrometer, Bavarian porcelain ware (imported) of which they still have a supply. Dr. Lenz and Messrs. Naumann, Greenberg and Kartenhaus were in charge.

Emil E. Lungwitz, New York, exhibited the Kelly filter press in conjunction with L. O. Koven & Brother. This was a regular size press of which all the features could be examined. Dr. Lungwitz was in charge.

Macbeth-Evans Glass Company, Pittsburgh, Pa., showed chemical glassware made in U. S. A. to take the place of Jena ware. This included all sizes and shapes of beakers and flasks. Messrs. George D. Macbeth and F. S. Irving were in charge.

Merck & Company, New York City, exhibited a shelf of their well-known "blue label" reagents and large jars of hydro-quinone (manufacture in the United States begun in 1914), synthetic carbolic acid, pure benzol, aniline oil and other products.

Metallurgical and Chemical Engineering placed its booth at the disposal of visitors and exhibitors with respect to telephonic, clerical and stenographic service. Mr. Burns was in charge. Messrs. Muir, Bedell, Munn, Bergen, Cain and Hays were in attendance.

The Mogul Company, New York; exhibit of their liquid for treating miscellaneous materials to render them acid and waterproof; also of materials treated by their products. Messrs. A. Gottlieb and C. H. Klepper were in charge of the booth.

Monsanto Chemical Works, St. Louis, Mo.:—Samples of acetphenetidin, caffeine, chloral hydrate, coumarin, phenolphthalein, saccharin and vanillin. Mr. B. M. Couvalt was in charge.

J. L. Mott Iron Works, New York City, showed cast-iron steam-jacketed porcelain-lined mixer and other acid resisting kettles of different kinds. Mr. R. H. Horne was in charge.

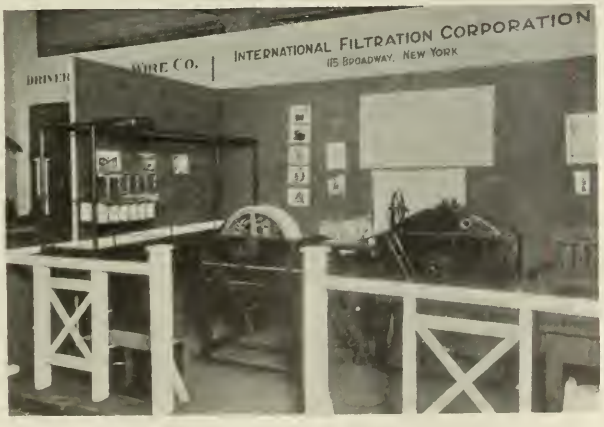
National Aniline & Chemical Company, New York City (selling agents for Schoellkopf Aniline & Chemical Company, Buffalo, N. Y.), had a fine exhibit of aniline colors and intermediate products, of which they have been the oldest American manufacturers. Mr. Henry Metz was in charge. Mr. I. F. Stone, president of the company, presented an admirable paper on Wednesday night on the aniline dye situation, which is printed in full elsewhere in this issue.

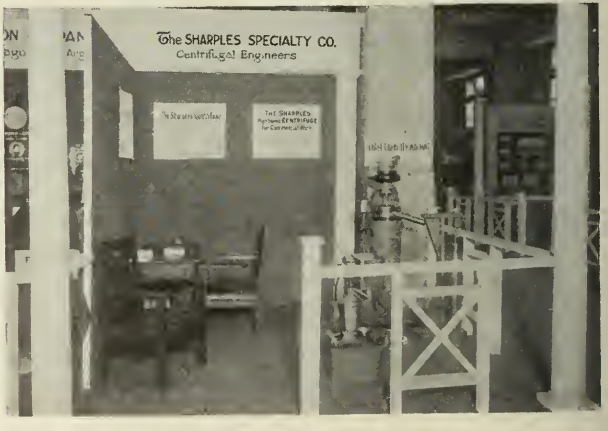
Norton Company, Worcester, Mass.;—Exhibit of alundum crucibles, tubes for carbon determination and various other refractory apparatus of alundum. A demonstration was made of the porosity of alundum by constantly dropping a liquid through a crucible of this material. Grinding materials were also shown. The columns at the corners of the booth were built up of grinding wheels. The booth was in charge of Mr. M. A. Williamson.

Pfaudler Co., Rochester, N. Y.:—Exhibited an upright open tank, and an upright open jacketed tank lined with their acid proof enamel. These were small tanks but the construction was on the same basis as many of their larger tanks. Messrs. F. L. Craddock and N. G. Williams were in charge.

Raritan Copper Works, Perth Amboy, N. J.:—Exhibited ingots and wire bars of refined copper; also nickel sulphate and copper sulphate recovered. Their exhibit of selenium and tellurium, which are by-products, deserves especial mention. Selenium was exhibited in several different forms, namely, viz: red amorphorus as powder, vitreous form as powder, sticks and half-pound cakes. Tellurium was in sticks and cakes. Besides this there were gold, silver, platinum and palladium. Messrs. S. Skowronski and C. H. Aldrich were in charge.

The Research Corporation, New York City, showed a small working model of the Cottrell electrical precipitation process for removing dust from gases. Frequent demonstrations were given and attracted a great deal of attention. The voltage used was about 40,000, whereas in actual practice up to 100.000 volts are used. The transformer was furnished by the American Transformer Co., Newark, N. J.





Exhibits at First National Exposition of Chemical Industries

New York, September 20 to 25, 1915

Mr. Linn Bradley of the Research Corporation and Mr. W. F. Hubley of the American Transformer Co. were in charge.

Schaeffer & Budenberg Company, Brooklyn, N. Y., exhibited recording gages and thermometers of their Columbia and Crescent brands; also steam calorimeters, engine indicators, and stationary and hand tachometers. Their recording apparatus was demonstrated by a complete testing outfit. Messrs. Wimmers and Undertsch were in charge of the booth. Great credit for the attractive arrangement of it is due to Mr. Carlier.

Schaum & Uhlinger, Philadelphia Pa., exhibited the parts of a small centrifugal; also a small undriven basket type centrifugal together with photographs of their various designs. Messrs. C. W. Schaum and Leslie Griscom were in charge.

Schutte & Koerting Company, Philadelphia, Pa., had a complete working installation of the Bihn-Jones automatic air-lift except that the lift was not so high as would be encountered in practice. They also exhibited the Auld reducing valve for steam and air reduction, lead-lined valves and ejectors and various other engineering specialties. Dr. E. Kimberly was in charge.

E. Scott & Co., Fall River, Mass., showed photographs and blue prints of plants and machinery designed and installed by them, especially vacuum and distillation plants. Messrs. H. Austin and A. B. Kennedy were in charge.

Sharples Specialty Co., West Chester, Pa., showed their smallest and largest types of centrifugals. Principal interest in these machines is their high speed, the small one travelling at 20,000 r.p.m. and the large one at 40,000 r.p.m. They are hung from balls and are free at the bottom.

Sowers Manufacturing Co., Buffalo, N. Y., showed two standard type "Dopp" seamless kettles and a small experimental vacuum kettle. Messrs. C. M. DeForest, W. Bowman, and P. Coxe were in charge.

Stamford Manufacturing Co., New York City, showed furs, silks, buttons, wool, cotton and leathers dyed with their vegetable dyes. The logwood produces the blacks and blues, the fustic produces the yellows and browns, the hypernic produces the reds, and these are further mixed to produce other shades. Mr. C. L. Young was in charge.

Sweetland Filter Press Co., New York:—The demonstrations of this filter press attracted very considerable attention as a complete small working filter was in operation with the necessary solutions, etc., for a complete demonstration. The metallic filter cloth used in conjunction with the press was also a source of much interest. Messrs. A. W. Wright and Howard Runyon were in charge.

Swenson Evaporator Company, Chicago, Ill., exhibited two of their standard evaporators, one the standard horizontal tube evaporator of the submerged tube type, the other the patented basket type, vertical tube "Seco" evaporator having 250 sq. ft. of heating surface by passing the liquid up through vertical tubes surrounded by steam in the basket, the vapor emerging at the top of the tubes. Messrs. F. M. De Beers and P. B. Sadtler were in charge.

Tennessee Power Company, Chattanooga, Tenn., exhibited photographs and maps showing their completed and proposed hydro-electric developments on the Ocoee and Tennessee rivers. Messrs. E. A. Hitchcock and C. F. Long were in charge.

Thwing Instrument Co., Philadelphia, Pa.:—Thwing Pyrometers, high-resistance multiple-recording pyrometers, also duriron and carborundum protecting tubes for thermocouples. A feature of their exhibit was a new apparatus for directly reading the moisture content of coal. The exhibit was in charge of Dr. Charles B. Thwing.

Toch Brothers, New York City, exhibited the different pigments used in making R. I. W. paints; also finished surfaces and hollow tile showing their water-proof paints and photos showing the many large buildings on which their paints are used. Among these are many of the largest structures in New York City. Messrs. E. A. Marx and F. A. Milligan were in charge.

Tolhurst Machine Works, Troy, N. Y., had on exhibit a large centrifugal driven from above and also two small laboratory centrifugals. Messrs. Tolhurst and Patton were in charge.

Troegerlith Tile Co., New York City:—Samples of their tile flooring in all different colors, their cork composition flooring, "Pollo Oil" and N. B. water proofing for floors. Messrs. Hyde, Richardson and Cheney were in charge.

Union Sulphur Company:—Refined sulphur and a most interesting sample of synthetic indigo made within the last two weeks by a Michigan manufacturer who wishes to withhold his name. Mr. Wilkinson was in charge.

United Gas Improvement Company, Philadelphia, Pa., exhibited by-products of coal-tar distillation, including intermediates, light refined products, road compounds and pitches.

United Lead Company, New York City:—Lined and covered pipe, in lead, tin, brass and copper. Lead rope for caulking. Ulcoloy, a new alloy of 50 per cent Cu. and 50 per cent Pb. They also had on exhibit a piece of lead pipe 2000 years old from Rome. This was well preserved and attracted considerable attention. Messrs. L. B. Gallison, Thomas Wettstein, E. J. Bredehoft and O. M. Hovemaner were in charge.

U. S. Government Departmental and Bureau Exhibits, Washington, D. C.:—This was the largest exhibit and contained a great volume of interesting apparatus, photographs, materials and publications. The feature which attracted the most attention was the demonstration of the Rittman oil cracking process, for making gasoline, benzol and toluol from petroleum. The Bureau of Foreign and Domestic Commerce showed all their publications, the Bureau of Mines showed the Westphalia and Draeger apparatus for mine rescue work; also Edison's electric mine lamp, first-aid cabinets and oxygen reviving apparatus. The lungmotor adopted by the U. S. army and navy was shown. The Geological Survey showed some of the economic minerals studied by them, and their various publications. Among the minerals were alunite, niter from Oregon and crude K_2SO_4-40-50 per cent obtained from the water of Owen's Lake, Cal. The agricultural and forestry service were represented by publications and photos. The Bureau of Soils and Plant Industry showed different fertilizers, kelps and brine from Searles Lake, Cal. The Bureau of Census was represented by their publications on chemical industries. The Bureau of Standards had a very large exhibit showing all their publications and the apparatus used in their work. This included gas calorimeters and meters, pyrometers, thermometers, hydrometers, standard weights, chemical apparatus and much other material. The following men were in charge: Bureau of Mines, Mr. M. F. Leopold; Rittman Process, Mr. S. H. Hartig; Foreign and Domestic Commerce, Dr. Thomas H. Morton, W. A. Johnston, Jr., Messrs. Brock and Penfield; Bureau of Standards, Dr. William Blum, E. C. McKelvy.

U. S. Smelting, Refining & Mining Co., Boston, Mass.:—Specimens of products from all of their subsidiary companies including different brands of copper, lead, spelter, selenium, gold, silver, platinum, palladium, crushed slag, hydrofluoric acid and miscellaneous ores. Also an exhibit showing the different stages in the process from ore to refined copper. Messrs. Sidney Rolle, A. Butts and W. C. Smith were in charge of this very well arranged and representative exhibit.

Valley Iron Works, Appleton, Wis., had on exhibit a complete Vesuvius sulphur burner, so arranged that all parts could easily be seen. Messrs. E. A. Peterson and R. W. Fannon were in charge.

Wilson-Mauelen Company, New York, who are shortly to move to their new factory at Whales Avenue and 142nd Street, Bronx, New York, had their "tapalog" on exhibition. This is a multiple-recording pyrometer giving on one chart four records and four colors of the temperatures of four different sources of heat. Mr. Wilson was in charge.

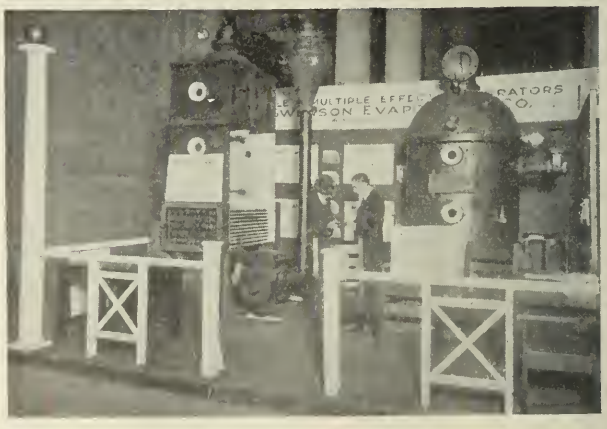
Zaremba Company, Buffalo, N. Y., showed interesting photographs of their evaporating apparatus of different sizes and designs.

Official Opening of the Exposition

The exposition was officially opened in the lecture hall on Monday evening. Dr. C. A. DOREMUS introduced the speaker of the evening, Dr. CHARLES H. HERTY, president of the American Chemical Society.

Dr. Herty, in his own delightful way, said there could be no more pleasing privilege than to open the First National Exposition of Chemical Industries ever held in this country and to extend congratulations to its originators, and he expressed the hope that the exposition might help the American public to find the right attitude toward the American chemist.

The German chemist has been largely responsible for the industrial successes of modern industrial Germany. Now since the war has cut off the importation of many chemical and allied products from Germany to this country, the American newspapers and the American public have found fault with the American chemist. But the American public should remember that as a nation it has never taken the same friendly attitude



Exhibits at First National Exposition of Chemical Industries

New York City, September 20 to 25, 1915

toward the American chemist which the German nation has taken toward the German chemist. This is a fact.

What is needed for the further development and growth of the chemical industry in America? The chemical manufacturer needs a little time to adjust himself to changed conditions. Brains and punch the American chemist has. But American ingenuity and energy cannot do without American capital, and American capital hesitates to make investments if they are to be rendered insecure by a sudden stoppage of the war. What is needed is protection—not forever, but just for a reasonable time until the American chemical industry has adjusted itself to new conditions. Dr. Herty's plea for a protective tariff for a limited time was very strong.

Dr. Herty also emphasized that now when the interest of the nation has been aroused in the chemical industry the public should be seriously warned against stock-jobbing concerns which are playing on the aroused interest in chemistry. It is the legitimate chemical industry which must be protected in its present healthy growth.

American Electrochemical Society Meeting

On Tuesday night a meeting was held at the Lecture Hall of the exposition by the New York section of the American Electrochemical Society.

Dr. COLIN G. FINK, of the Edison Lamp Works of Harrison, N. J., chairman of the section, opened the meeting by defining electrochemistry as the science which treats of the production of electricity by chemical changes, of the production of chemical changes through the agency of electricity, and of the electrical properties of chemical substances.

Electrochemistry became a real science in 1887 when the master mind of Wilhelm Ostwald systematized and interpreted the empirical results and generalizations of Berthelot of France, of Guldberg and Waage of Norway, of Willard Gibbs of America, of van't Hoff of Holland, of Arrhenius of Sweden, of Faraday of England, and of Bunsen of Germany. Electrochemistry has a decidedly cosmopolitan pedigree.

From an economic and commercial standpoint our own country ranks as the most important electrochemical center of the world.

Dr. Fink then introduced as the first speaker Mr. DAN. T. PIERCE of the Barber Asphalt Company, with "his lively troup of trained molecules."

Mr. Pierce spoke on the properties and methods of mining and utilizing of Trinidad asphalt, showing a set of most interesting moving pictures. But the most interesting and highly novel part of his lecture was what he said about colloidal clay in Trinidad asphalt. For the first time the Brownian movements of colloids were shown in a moving picture on this evening.

There is a very important difference between Trinidad asphalt and any other bitumen in commercial use or of which we have any knowledge. This difference lies in the fact that Trinidad asphalt in its natural state contains a considerable proportion of mineral matter in colloidal form. That is to say, mineral particles so finely divided that they cannot be settled out or filtered out, and which are in constant motion.

For a great many years it has been observed that there was a small residue of mineral matter recovered from the most carefully filtered solutions of Trinidad asphalt. This residue was never identified or satisfactorily accounted for until Mr. Clifford Richardson, the engineering chemist of The Barber Asphalt Paving Company, conceived the idea that this matter consisted largely of colloidal clay. This conception on Mr. Richardson's part followed closely upon a lecture on colloids by Professor Ostwald at the laboratory of the College of the City of New York, in March, 1914.

Subsequent investigations with the aid of the ultra-microscope and the laboratory work carried out by Mr. Richardson and his assistant Dr. Schneeberger, have verified the belief that in Trinidad asphalt we have a true bitusol—that is to say, dispersed solid colloids in solution in bitumen. The extreme fineness of this colloidal matter is demonstrated by the fact that it is not deposited from solutions of the bitumen after standing for years, and that under the ultramicroscope it is demonstrated to be in that active state of motion called the Brownian movement which is characteristic of all highly dispersed colloidal material.

The moving pictures [shown by Mr. Pierce] are unique in that they afford the first opportunity to observe the Brownian movement of colloidal matter in form of moving pictures. These pictures were taken by joining the lens of a cinematograph camera to the eye-piece of the ultramicroscope, thus reproducing on the film the movement observed by the eye through the microscope. So far as is known this is the first time such a motion picture has been made and this is the first exhibition of the film.

When it is considered that the colloidal particles are as small or smaller than one ten-thousandth of a millimeter, this example of motion photography becomes all the more remarkable.

A few words will emphasize the importance of Mr. Richardson's discovery with relation to the asphalt paving industry. The theory of an asphalt pavement is that of a mixture of sands in which by grading the voids will be reduced to the lowest possible limit, bonded together with the asphalt. A mixture contains from, say, 12 to 18 per cent of filler dust which will pass a screen of 200 meshes to the inch. The larger the proportion of fine sand in a mixture the more bitumen it will carry and the more durable will the pavement be, for the obvious reason that the more finely the mineral matter is divided, the larger surface area it presents for the adhesion of the asphalt.

The presence of colloidal matter carries us a step further, for not only does colloidal matter add to the paving mixture particles of a fineness never artificially combined with bitumen—it also gives us the advantage of the absorptive power of colloids. That is to say, the power such matter has of holding the asphalt cement about itself in the form of a film.

The filler ordinarily used in an asphalt mixture is estimated to run about 192,000,000,000 particles to the pound, and none of it is of colloidal fineness. The dimensions of such filler would be from 8/100 to 25/10,000 of a millimeter. Imagine a cube having a dimension of 1 centimeter reduced to particles of the coarsest colloidal size—1/10,000 of a millimeter—and we have increased the surface area of the material in the 1 centimeter cube 100,000 times.

The importance of colloidal matter in an asphalt mixture is therefore due to two causes, namely, the vast increase in the surface area presented, and the tenacity and thickness of the film of asphalt which surrounds the colloidal particles.

For many years the industry has been familiar with what it called the "stability" of Trinidad asphalt. Colloidal chemistry has now enabled us to account for this characteristic on rational grounds.

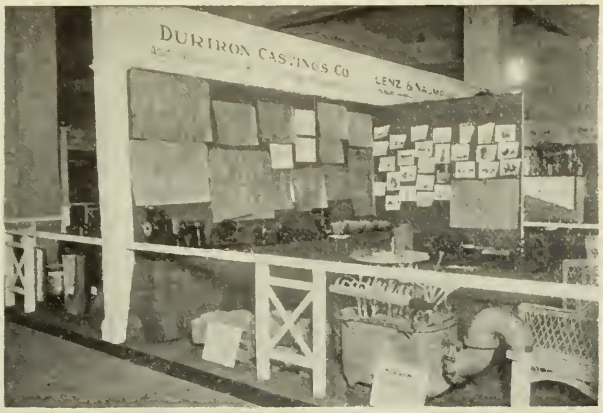
Mr. LINN BRADLEY, of the Research Corporation, followed with an interesting address on "the solution of the smoke, dust and fume nuisance by electrical precipitation" by the Cottrell process. This address gave a very good concise summary of the present status of the process, and is reserved for publication in a future issue.

The last speaker of the evening was Mr. HARRINGTON EMERSON, who spoke on "efficiency in the conservation of our natural resources." His theme was: "Utilizing Efficiently Our Natural Resources."

The natural resources of the universe become *our* natural resources when we can use them for our service. They are only partly our resources when we merely adjust ourselves to them as parasites. They are distinctly ours when we can control and harness them. About sixteen years ago, I visited Snoqualmie Falls, near Seattle. A great river plunged over a ledge and fell to the gorge below, a height 100 ft. greater than that at Niagara. Here was a tremendous natural resource, not yet harnessed, not yet ours.

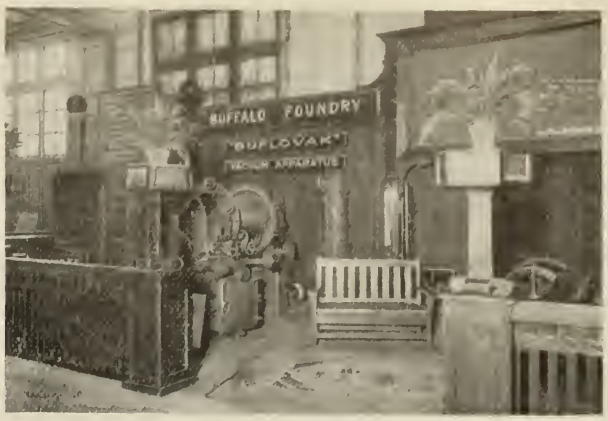
I visited the same falls this summer. Scarcely a brook trickled over the bared ledge, but miles away in Seattle and in Tacoma, trolley cars were running, machinery was driven, lights were blazing, because the falls had been harnessed and controlled. The natural resource was *ours*, and it was being efficiently utilized in forms that were no longer natural, but distinctly a product of man's mind.

To utilize efficiently our natural resources we must know what resources are natural, what is their extent,



Exhibits at First National Exposition of Chemical Industries

New York City, September 20 to 25, 1915



Exhibits at First National Exposition of Chemical Industries

New York City, September 20 to 25, 1915

what control we can attain over them, what part of those controlled has value, what the maximum value is, our efficiency in extracting the values.

Natural resources are physical, mental and emotional. The sun is one of our greatest natural resources.

The evaporation of water is one of the most universal phenomena in nature, but it took millions of years before an animal wise enough to boil water appeared on earth, and it took several hundred thousand years more before man was wise enough to confine steam in a strong container and make it push a piston. . . .

The radiations from the sun are incomparably our greatest natural resource, but as yet the efficiency of utilization is very low. There is probably no field so promising of immediate great returns as more efficient utilization of that small fragment of the sun's radiation which the earth intercepts. At the present time only about one-thousandth part is utilized at all. It is conceivable to me that we may ultimately discover some device by which condensation of the moisture of the air into rain can be concentrated at one point, even as we now divert the water of a stream into a flume, lead it many miles away and there harness it. More immediate and practical is our power to make the sun serve us by planting and covering the available surface of the earth with more suitable vegetation.

Mr. Emerson then discussed our natural mental and emotional resources.

The human seed is so small that it requires a microscope to be seen. Give this seed nourishment, heat, sunlight, and air, and it grows, perhaps into one of the great leaders of humanity. Socrates was the teacher of Plato, Plato was the teacher of Aristotle, Aristotle was the tutor of Alexander, and at 33 Alexander was weeping because there were no more worlds to conquer. What kind of a world would it be if the human plasm developed exclusively into such sequences as I have enumerated?

On the one side we would have the infinite material universe extending from the center of the earth to the uttermost confines of space, and on the other infinite mental and moral capacities of human excellence utilized efficiently to conquer these infinite resources for the benefit of humanity. These are the two biggest problems in the world as I see them and every act, every thought, every emotion can be gaged with reference to their solution. By far the more important of the two is the efficient use of the human elements.

Mr. Emerson then gave instances how some nations do better with their natural resources than others, so that we can at least set up comparative standards. "Henry Ford is able to make American mechanics worth to themselves $5 a day instead of $3. He makes the worth of his company $10 a day instead of $4. If all American workers were doing as well as the Henry Ford workers they would be earning $40,000,000 a day more for themselves and would be producing $80,000,000 more a day than the workers now do."

Meeting of the American Institute of Chemical Engineers

On the evening of Wednesday, Sept. 22, a meeting of the American Institute of Chemical Engineers was held. The president, Dr. GEORGE D. ROSENGARTEN, made a few opening remarks and then introduced Dr. THOMAS H. NORTON, of the Department of Commerce, Washington, D. C., who spoke on "Foreign Markets for American Chemicals." The first part of the lecture was augmented by numerous lantern slides, showing the loading, unloading and transportation of American goods in foreign countries. This part of the talk was very general and included such apparatus as agricultural implements, oil engines, cement, etc. He emphasized

the importance of packing goods for export very securely, and showed pictures of damaged goods which had arrived in foreign port. Every facility of the Department of Foreign and Domestic Commerce is open to manufacturers to assist them in their export problems.

Detailed statistics were then given showing the increase in our exports of chemicals during the last year, the figures for the month of June, 1915, showing a 161 per cent increase over the month of June, 1914. Data are now being obtained on the geographical distribution of the export increases. The chemical market of the world was placed at $598,000,000 in value, the share of the United States being but $48,000,000.

The potash situation was then briefly discussed, and the active part which the Department of Commerce has taken in this work was explained. Many processes have been proposed, but few are commercially available. The efforts to solve the potash problem are sure to avail something before very long, but the commercial process and the capital must be brought together.

The dyestuff situation was next briefly discussed as of equal importance to potash. The Department of Commerce has also taken an active interest in working out this problem and has endeavored to bring the capitalists in touch with the engineer and chemist. Dr. Norton thought it might be a year or two before our production of dyes would equal our demand, but if sufficient protection is assured we are bound to have our independent industry.

Mr. I. F. Stone, president of the National Aniline and Chemical Company, then presented a lecture on the aniline dye situation. This lecture is given in full elsewhere in this issue.

Meetings of the American Paper and Pulp Association

On the morning and afternoon of Thursday, Sept. 23, the newly formed technical section of the American Paper and Pulp Association held two well attended and very interesting sessions. The morning session was opened by the presidential address of Mr. Frank L. Moore. Other papers on the program for the two sessions were:

"Some Experiences in Refining Groundwood Slivers," by D. L. Bellinger.

"A Method of Determining the Current Capacity of a Cell in an Electrolytic Bleach Plant," by F. B. Wheeler.

"The Relation of Ink and Paper in Halftone Printing," by H. P. Carruth.

"The Possibilities of Accurate Determination of Groundwood in Papers," by Max Cline.

"Work of the German Association of Cellulose and Paper Chemists," by Henry F. Obermanns.

"Suggestions for the Adoption of Standard Tests and Processes," by Otto Kress.

"The Elimination of Fuzz in Soda Pulp by Proper Cooking Conditions," by S. D. Wells.

"Prospects of Relieving the Scarcity of Dyestuffs Used in the Paper Industry," by I. F. Stone.

Meeting of the American Chemical Society

The meeting of the New York Section of the American Chemical Society on the evening of Friday, Sept. 24, was opened by the address of the chairman, Dr. T. B. Wagner.

Dr. Leo H. Baekeland followed with an admirable address on "Industrial Chemistry." This is published in full on page 677 of this issue.

Mr. Howard H. Gross, president of the Tariff Commission League, spoke on "The Tariff Question" (See page 676 of this issue).

The concluding address of the evening was made by Dr Sam. P. Sadtler, of Philadelphia, Pa., on "Some American Contributions to Industrial Chemistry." The chief part of this lecture dealt with the development of the American petroleum industry, but the author also dealt with the fertilizer industry, the water gas process, the industries of sulphur, cottonseed oil, starch production, and the electrochemical and electrometallurgical industries. An account of this interesting lecture is reserved for one of our next issues.

Other Lectures Held at the Exposition

The afternoons were devoted partly to the demonstrations of moving pictures and partly to special invited lectures. The program of the latter included the following:

"Accident Prevention in the Chemical Industries," by Fred W. Keough.

"Transportation and Shipping Facilities with Foreign Countries," by Welding Ring.

"The Manufacture of Chocolate," by D. C. Lightner.

"Explosives," by J. L. Taylor.

"Potash," by H. A. Huston.

"Paint," by G. B. Heckel.

"Chemical Effect of Dynamiting the Soil," by Geo. Frank Lord.

"The History of Cement," by E. S. Conwell.

"The X-ray," by W. D. Coolidge.

"Refined Tars for Road Construction and Maintenance," by Philip Sharples.

"Synthetic Phenol and Picric Acid," by A. H. Ney (published in full on page 686).

"Research and Progress in American Manufacturing," by Raymond F. Bacon.

"Manufacture of Vegetable Oils," by Charles V. Bacon.

"Alundum and Crystolon," by M. A. Williamson.

"Heat Insulation with Kieselguhr," by D. S. Collins.

"The Evolution of the Glass Industry," by Robert L. Frink.

"The Possibilities of Niagara for American Electrochemistry," by Thomas H. Norton.

"The Great Pan-American Opportunity," by John Barrett.

"Opportunity for American Chemical Industry," by E. E. Pratt.

The three last-named lectures were presented in the concluding session, held on Saturday night under the auspices of the New York Section of the American Electrochemical Society, with Dr. Colin G. Fink in the chair. We reserve a number of these lectures for publication in future issues.

Recent Chemical and Metallurgical Patents

Oils

Catalyser for Hydrogenation of Fatty Oils.—A catalyser of electrolytic nickel for the hardening of fatty oils is patented by Carleton Ellis of Montclair, N. J. The method of preparing this nickel is to deposit it from the sulphate or ammonium sulphate solution using a nickel anode, and as cathode a mass of powdered charcoal, graphite or a metal support, capable of occluding hydrogen. The nickel may deposit in the form of a spongy mass on the charcoal particles, powdered graphite or metal support. A current of relatively high density is employed for this purpose. Five per cent of a titanium salt may be added or a small amount of zinc sulphate. The titanium aids in hydrogen absorption

and the zinc sulphate favors the production of a spongy nickel.

The prepared catalyser is introduced into fatty oil heated to 180 deg. C. Hydrogen or a hydrogen-containing gas is introduced and the oil hardened to the desired point. The catalyser may be placed in a tower through which the oil is caused to flow, or it may be agitated with the oils in the presence of hydrogen. The catalyser may be regenerated when it becomes spent by oxidizing and again reducing.

The advantage claimed for this catalyser is that it provides a pure material which may be used for a considerable length of time without becoming poisoned. In wet methods, such as precipitating nickel by alkali from the sulphate solution, it is difficult to free the precipitates from sulphates, and sulphides may form when the precipitate is reduced with hydrogen at 350 deg. and catalyser will be poisoned. The reduction by hydrogen also has a tendency to sinter the product, thereby causing a loss in catalytic value. The use of nickel without a carrier of clayey material removes an objection to the catalytic process, viz., the disagreeable earthy taste imparted to the oil by the clayey material which is difficult to remove. (1,151,003, Aug. 24, 1915.)

Iron and Steel

Process of Treating Cast Iron.—For certain purposes it is desirable that all of the oxygen should be removed from cast iron in order that the iron may be free from chilling properties and the carbon in the flaky graphite rather than the combined form. A process for accomplishing this purpose is patented by Joseph E. Johnson, Jr., of New York City. In this process the cast iron is heated in an electric furnace, preferably of the inductive type, to about 3000 deg. Fahr. This causes the occluded oxygen to combine with silicon and iron present, silica rising to the top of the bath, and CO escaping as bubbles. In order not to have an oxidizing atmosphere above the bath, CO gas is injected into the chamber above the charge, even up to 100 per cent if necessary. Hydrogen or any satisfactory gas could also be used, or a vacuum may be maintained above the charge. The process is preferably carried out in an induction furnace, as the high conductivity of the bath would require very large electrodes were an electrode furnace used. (1,150,201, Aug. 17, 1915.)

Alloys

Copper-Titanium Magnesium Alloys.—In the elimination of gases and deleterious substances from copper and copper alloys for casting purposes cupro-titanium has been used. In order to still retain the effects of the titanium and further improve the metal it is proposed, in a patent of Charles Vickers of Niagara Falls (assigned to the Titanium Alloy Manufacturing Company) to add an alloy of copper, titanium and magnesium to the bath of molten metal. It is believed that the titanium combines with the oxygen and other undesirable elements forming titanic acid and the compounds of magnesium combine with them to form slags so fusible that they are entirely eliminated from the bath. The surface of the resulting castings are substantially free from undesired specks and blemishes. Ordinarily the constitution of the alloy to be added would be about 5 per cent titanium, 93 per cent copper, and 2 per cent magnesium. Usually about ten minutes is required for the elimination of impurities. (1,151,744, Aug. 31, 1915.)

Alloys of Iron, Cobalt, and Chromium.—Ternary alloys of iron, cobalt, and chromium are described in a patent issued to Elwood Haynes of Kokomo, Ind. In a previous patent (No. 873,945) he described alloys of cobalt and chromium which had many valuable properties. As a rule the hardness increased with the amount of chromium present. These alloys were somewhat difficult to work, and were costly on account of the high temperature required. Their hardness is also greater than is required for making knives, auger bits, gimlets, etc., and filing and grinding are somewhat difficult. The addition of iron softens these alloys to any desired degree, but they will be of sufficient hardness for saws and similar tools, being as hard or harder than the ordinary tempered steel. A series of these alloys with low carbon content was prepared with a constant percentage of chromium (20 per cent) and percentages of iron from 10 to 75 per cent. They show little variation in physical or chemical properties so long as they contain 5 per cent or more of cobalt and from 20 to 25 per cent of chromium. They are malleable at a bright red heat and retain a beautiful luster. Several bars of these alloys were ground smooth and covered with a strong solution of ammonium chloride. These were then subjected to moist air for several days, but failed to show any stain or tarnish. It is desirable to have a low percentage of carbon (1 per cent or under) in these alloys. Ferrochromium may be used in making the alloys, but on account of its usual high carbon content, it is necessary to first remove the carbon. At least 10 per cent of chromium should be in these alloys to insure the desired properties, the preferable amount being 20 to 30 per cent. (1,150,113, Aug. 17, 1915.)

Notes

Overhead Trolley and I-Beam Carrying Equipment is described in the recent catalog of the Richards-Wilcox Manufacturing Co. of Aurora, Ill. Their apparatus are made for carrying capacities up to 4 tons, and are useful where floor space is limited.

Teniente Topics, a monthly booklet devoted to the interests of the Braden Copper Co. has been launched forth on its first issue in June. It is published at Sewell, Chile, by the Teniente Publishing Co., the company consisting of men connected with the Braden Copper Co. The object of the publication is to give descriptions of the daily activities at Braden for outsiders and to give also those at Braden descriptions of activities in other fields.

Reducing Sulphur Content at Robesonia Furnace.—After an exhaustive study, accompanied by numerous practical tests, of the possibility of reducing the sulphur content of its ore burden, the Robesonia Iron Co., at Robesonia, Pa., which specializes in low-sulphur, low-phosphorus pig iron, has adopted the recommendations embodied in a report by Mr. John W. Gocher, consulting engineer, of Johnstown, Pa., and is now constructing a plant, under his supervision, to carry out the plan proposed. At the present time the ore, which is from the well-known Cornwall mines, is roasted in Gjers kilns, the lumps as they come from the mine being roughly broken by hand before charging. It is proposed to crush and screen the ore, all that passes through a ⅜-in. screen to be sintered in Greenawalt sintering pans, while for the present all of the coarse ore, ranging in size from ⅜ in. to 2½ in., will be roasted in the Gjers kilns, as heretofore. It is expected that the sulphur content of the fine ore will be reduced from about 2.4 per cent as it comes from the mines to not over 0.2 per cent in the sinter. The coarse ore roasted in the kilns will average about 0.6 per cent sulphur. After a suitable trial period, with various proportions of sinter and roasted ore, if the results are as expected the amount of sinter will be gradually increased, with the idea of ultimately sintering all of the ore.

Rennerfelt Electric Furnace

The first Rennerfelt furnace was constructed in 1912 at Hallstahammars Iron Works in Sweden. In several important details the new furnace was quite different from previous types. Mr. Rennerfelt, under whose supervision the work was carried on, obtained such satisfactory results that within one year a steel foundry containing four Rennerfelt furnaces was established.

Since then the increased use of the furnace has been very rapid. By 1914, fifteen furnaces, ranging in size from 600 lb. to 3 tons, had been placed in operation or ordered, and by July 1 of this year this number had increased to thirty, of which four are found in England, five in Russia, two in Switzerland and the rest in Sweden and Norway. It is very well adapted for the manufacture of tool steel and steel alloys, for steel castings, for the melting of copper, brass, and for any other purpose for which a high heat and a quiet metal are required.

DESCRIPTION OF THE FURNACE

The Rennerfelt furnace has generally been built with a horizontal, cylindrical steel shell, supported on rollers or trunnions, and with one close-fitting charging and casting door on the side or in the end of the furnace. The shell is lined with asbestos board, next to which firebricks are built in rings. Inside this is the actual acid or basic lining.

Centrally in the roof and horizontally through the gables of the sides enter water-cooled bronze electrode-holders, through which slide three Acheson graphite electrodes turned to exact size. The diameter of these electrodes varies from 1½ in. for the small sizes up to 4 or 5 in. for the larger sizes. As stated, any available current can be used. In case of a direct current, the horizontal electrodes are coupled in parallel, while the vertical electrode is connected with the other pole.

If three-phase alternating current is used, it is converted in stationary transformers by the Scott arrangement into two-phase current at 70 to 110 volts. One phase of the current is connected to each side electrode. The central vertical electrode is connected to the common point between the two phases of the transformer. The currents entering through the horizontal electrodes neutralize one another, but the action of the returning current into the central electrode generates a magnetic field which deflects the arcs downward to the bath, forming an inverted arrow-head.

This form of arc is one of the special features of the Rennerfelt furnace. The heat generated in the arcs is concentrated in the bath, though the electrodes do not actually touch or even approach the slag or metal. The arcs are sweeping all over the central place underneath the points of the electrodes, insuring a uniform heating of the charge and rendering the slag very fluid and chemically active.

When the furnace is to be preheated the current is simply turned on, there being no necessity for solid fuel or metal in the furnace. This can be charged with cold or liquid metal. During the charging the electrodes may be drawn back and raised so as to prevent their being injured. Once the furnace is charged, the electrodes are adjusted into proper position, the door is carefully closed, and the current turned on.

For smaller furnaces the electrodes are manually adjusted. For larger furnaces automatic regulation is used. Only the horizontal electrodes need adjusting during the operation.

The consumption of electrodes is very low. In a 1200-lb. furnace running continually on charges of cold scrap and pig, the average consumption of electrodes has been found to be 5 to 6 lb. per ton of steel. Even when melting pig iron and afterward decarburizing it by means of ore, the consumption of electrodes has not exceeded 6.6 lb. per ton in spite of the highly oxidized slag carried in the charge.

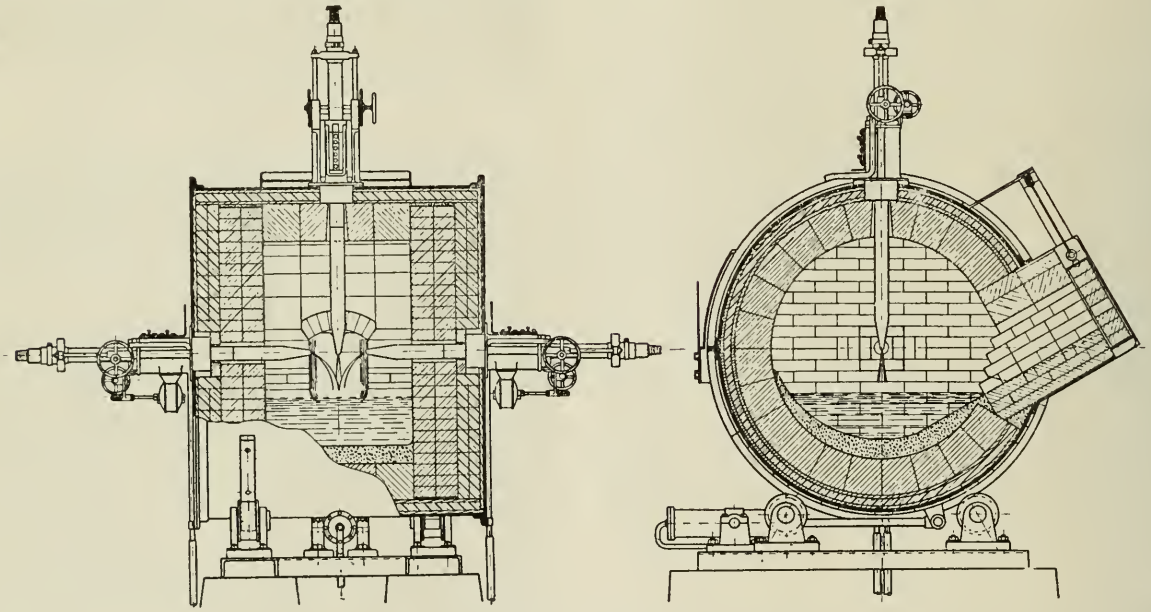


FIG. 1—RENNERFELT ELECTRIC FURNACE

Some curves are reproduced in Fig. 2 which illustrate the performance of the Rennerfelt furnace when melting cold scrap. The curves are obtained from a 600-kg. furnace running on tool steel in a Swedish mill at Trollhättan. The furnace is rated normally at 125 kw., but as indicated by the curves only about 100 kw. are utilized. It is running day and night on cold charges, drawing its power from the adjacent large government power plant.

Certain portions of the curves are also affected by the operation of some rolling mills, which caused very strong fluctuations in the power curve in spite of heavy flywheels provided to reduce fluctuation. The curve is rather peaky when the rolling mills are on, but comes down almost to a straight line at night and noon, when the furnace alone is working. The peaks of the furnace are comparatively low and rarely exceed 50 per cent of the normal load.

The 1¼-ton furnace is rated at 200 kw., and is being

operated without any automatic regulators or similar protective apparatus, receiving the surplus energy from a hydroelectric power plant of about 800-hp. capacity. Only an ordinary oil switch with time relays is needed to insure sufficient protection from the generators, the circuit breaker being adjusted so as to operate at 400 kw., or double normal furnace load. The furnace works as a large inclosed arc lamp, practically without any disturbing influence from the charge beneath the arcs.

Simultaneous readings of kilowatts, volts and amperes indicate a very satisfactory power factor. In one instance a value of 0.97 has been obtained at a furnace operated with a current of 50 cycles.

A very interesting paper on the use of liquid ferromanganese in the steel processes was presented by Axel Sahlin at the fall meeting, 1914, of the (British) Iron and Steel Institute. He speaks about the use of the Rennerfelt furnace in this connection and gives details of a number of tests made to ascertain the efficiency of the furnace. At one test, for instance, 1 ton of ferromanganese was melted in 2 hr. 45 min. The current consumption per ton amounted to 441 kw.-hr. at a temperature of 1500 deg. in the furnace when the metal

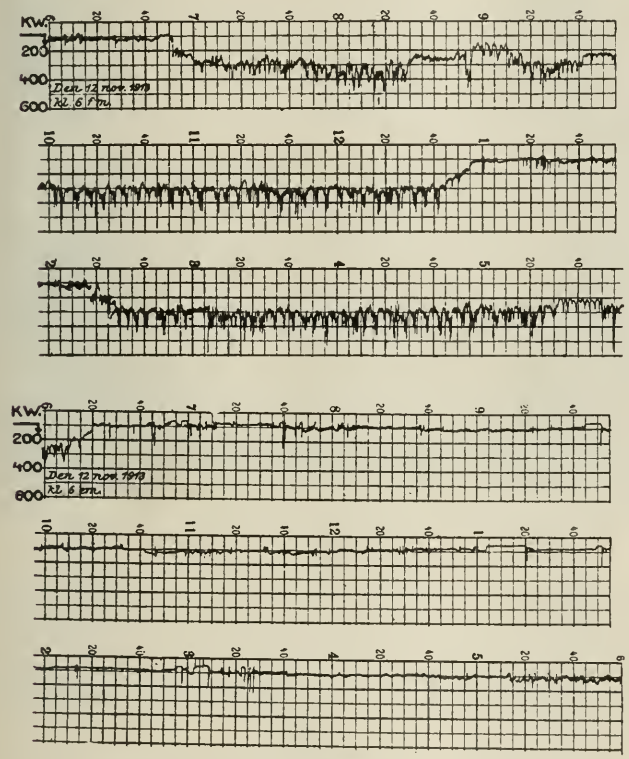


FIG. 2—FURNACE-PERFORMANCE CURVES

was charged. The corresponding efficiency of the furnace is 78 to 79 per cent. Loss of manganese was about 1 per cent.

	C. %	Mn. %	Fe. %
Analysis before melting.....	6.07	78.90	11.70
Analysis after melting.....	5.69	79.50	12.30

The steel produced by the Rennerfelt furnace is of excellent grade. From pig iron and ore, tool steel has been produced of equal quality with the best crucible steel.

A recent test of a piece of high-carbon steel produced in this electric furnace showed an elastic limit of 68,270 lb. per square inch and a tensile strength of 103,800 lb. per square inch with an elongation of 12.3 per cent. The steel analyzed C., 1.44 per cent; Si., 0.30 per cent; Mn., 0.36 per cent; S., 0.021 per cent, and P., 0.017 per cent.

Another piece with 0.96 per cent showed an elastic limit of 127,000 lb. per square inch and a tensile strength of 177,800 lb.

Soft steel with carbon around 0.20 is made daily in several of the Swedish plants. It is converted into steel castings of most intricate and thin-walled forms. Such steel has at testing shown a tensile strength of 60,000

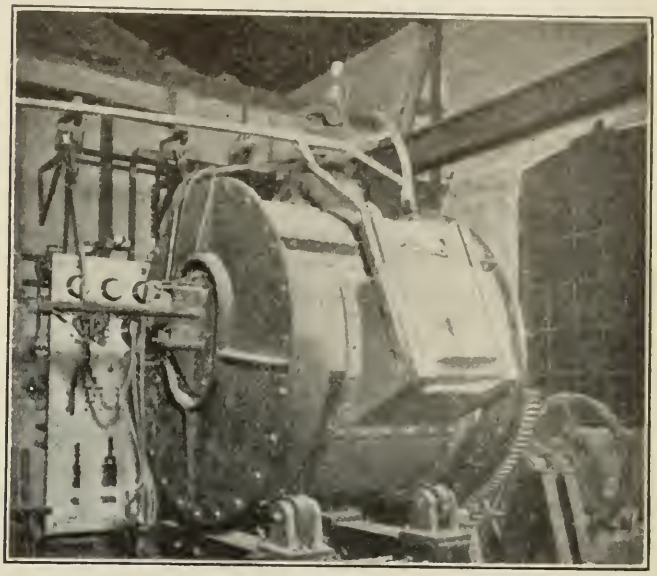


FIG. 3—1¼-TON FURNACE, HALLSTAHAMMAR WORKS

to 75,000 lb. per square inch, with an elongation of 20 per cent and more.

The Rennerfelt furnace is being introduced in this country by Messrs. Hamilton & Hansell, 17 Battery Place, New York City.

Protecting Polyphase Motors Against Phase Failure and Reversal

Accidental rotation of a motor in a direction opposite to that which the operator expects is often liable to result disastrously. An elevator may be dashed to the pit or through the overhead—costly machines, cranes, hoists, etc., may be seriously damaged if the direction of rotation is unexpectedly reversed when the starting device is closed. With alternating-current polyphase motors this may happen due to reversing of the phases and engineers have turned their attention to the problem of eliminating this source of accident. Failure of one phase may also cause burning out of the motor.

PHASE-FAILURE AND PHASE-REVERSAL PROTECTIVE DEVICE

A new compact type of phase failure relay, shown in the accompanying illustration, has been developed in the engineering department of The Cutler-Hammer Manufacturing Company, Milwaukee. This device is suitable for use on any system similar to a vertical motor having a two or three-phase stator winding and a squirrel cage rotor winding. The rotor shaft extends at the top, and to this extension a casting is secured carrying contacts designed to close a pilot cir-

cuit which controls the motor starter. This phase failure relay provides against abnormal drop in voltage, against failure of one of the phases and against reversal of the phases.

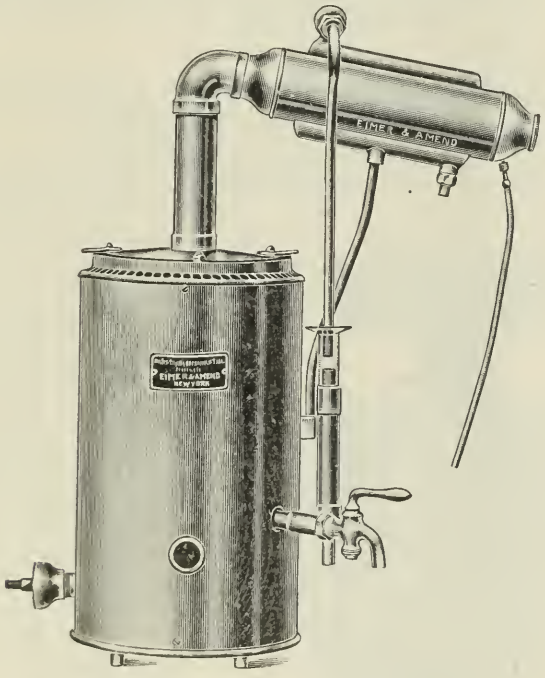
If the supply voltage falls below about 70 per cent of normal the relay opens the control circuit of the motor controller and keeps it open until the line voltage returns to at least 85 per cent of normal. These limits tions.
can be adjusted before shipment to suit special condi-

In case of phase failure, caused by the opening of one of the supply lines at any point, the relay opens the control circuit if the motor is under appreciable load and keeps it open until the fault is corrected. If the load on the motor is very light, so that no harm would result from its running single phase on account of the phase failure, the device may not operate until the load is increased or the motor shut down. If the motor is at rest at the time of phase failure the relay will act immediately. Thus the motor is allowed to run as long as no damage can result.

In case of phase reversal the relay opens the control circuit immediately and keeps it open until the phases are reconnected in the proper order. Accidents due to the motor running in the wrong direction when started up are avoided.

Water Distilling Apparatus

The necessity for distilled water of a high degree of purity in laboratories and manufacturing operations has led to the development of more efficient apparatus. The latest Barnstead-type water-stills furnished by Messrs. Eimer and Amend of New York City are for



BARNSTEAD WATER STILL, TYPE L

heating by steam, gas or electricity and the general type is shown in the accompanying illustration.

The operation of these stills is automatic and continuous. The water produced is free from ammonia, and all gaseous and organic impurities. The construction is such that the heat generated is used to preheat the incoming raw water.

The gas and electric types are portable and can be placed on the laboratory bench, or supported on a bracket attached to the wall.

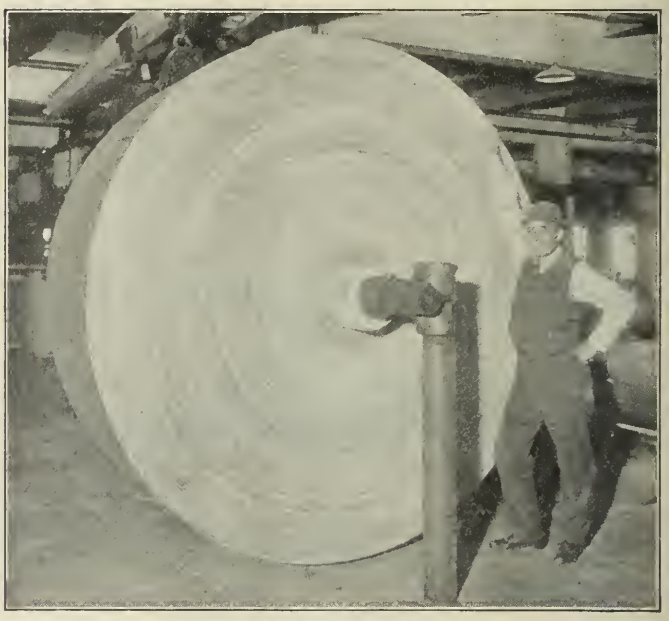
The boiler of the still is easily accessible for thorough cleaning by simply turning the thumb clamps which rigidly hold the condenser and hood to the boiler.

The electrically heated still is furnished with replaceable heating units which can be attended to by the operator.

Gigantic Conveyor Belts

Conveyor belts of great size have been tried and found successful by the California-Hawaii Sugar Refining Company. In February, 1906, they installed a 36-in. 7-ply Goodrich belt for the purpose of catching 125-lb. bags from a fall of 4 ft. and conveying them. This belt received and carried 2,000,000,000 lb. of sugar before showing any radical signs of wear.

Recently the same company ordered another belt from the B. F. Goodrich Company to be 1443 ft. long and 36 in. wide. This belt weighed 11,983 lb., and is shown in the accompanying illustration.



GIANT CONVEYOR BELT

Figuring eight hours' run without any delays a bag of sugar would drop onto the belt every nine seconds, and if the speed of the belt was such that it made twenty-six or twenty-seven revolutions every eight hours the bags would rest 12 ft. apart and a continuous load of 7500 lb. would be carried.

Chilean nitrate exports to the United States are reported to be again normal. Direct exports to certain European countries have increased somewhat, while to others they are entirely suspended.

An electric furnace for operating above 2000 deg. C. will be described in a paper to be delivered before the October meeting of the American Chemical Society in Pittsburgh by Mr. Frederick T. Snyder, president of the Snyder Electric Furnace Co. of Chicago. The furnace is adapted to be operated on powdered material.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in March, 1915, was sixty-three. The total quantity of ore milled during that period was 2,421,218 tons. There were 9840 stamps in operation, with an average duty of 9.35 tons per 24 hours. Tube-mills in commission numbered 314. The yield for the month was 753,935 fine ounces gold. The report indicates a larger tonnage milled and more equipment in operation than a year ago. The yield also shows an increase.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, OCTOBER 15, 1915 No. 12

Published Semi-monthly on the First and Fifteenth of Each Month by the

McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.

A. E. Clifford, Secretary. John T. DeMott, Treasurer

239 West 39th St., New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Col.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for October 15, 1915

EDITORIAL:

"Fair Protection" for the American Chemical Manufacturer 705
Non-Ferrous Metals During the War..... 706
Iron Industry Making New Records..... 707
The Naval Consulting Board..... 708
News from the Chemical Field..... 710
Papers by I. F. Stone on the Status of the American Chemical Industries in 1915 and by Maximilian Toch on the New American Barium Industry; Next Meeting of the American Institute of Chemical Engineers.
The Iron and Steel Market..... 711
Atlantic City Meeting of American Institute of Metals..... 712
The Range of Applicability of the Liquid Sulphur Dioxide Method for Determining Aromatic Constituents in Hydrocarbon Mixtures. By W. F. Rittman and R. J. Moore.... 713
Liquid Jets. By C. Terry du Rell..... 714
Notes on Concentration at Nevada Consolidated Copper Company (Editorial Correspondence)..... 716
Thermal Principles of the Blast Furnace. By J. E. Johnson, Jr. 718
Metallurgy at the International Engineering Congress—II.... 721
Symposia on Gold and Silver, Zinc, Lead, Fuels.
Opportunities for the American Chemical Industry. By Edward Ewing Pratt 729
Accident Prevention in the Chemical Industries. By Frederic W. Keough 731
National Exposition of Chemical Industries..... 734
A New Electrolytic Method of Sewage Disposal. By J. C. Olsen 735
Alloy Steels. By George L. Norris..... 739
The Co-Operative Metallurgical Exhibit at the Panama-Pacific International Exposition. By A. E. Wells and G. H. Clevenger 743
Vulcanized Fibre. By Charles Almy, Jr..... 746
The Electrolysis of Copper Sulphate Liquors Using Carbon Anodes. By Lawrence Addicks..... 748
Recent Advances in the Manufacture of Cyanogen Compounds. By J. E. Clennell..... 756
Foreign Markets for American Chemicals. By Dr. Thomas H. Norton 758
Recent Chemical and Metallurgical Patents..... 762
Synopsis of Recent Chemical and Metallurgical Literature 764
Viscosimeters. By R. F. MacMichael..... 767
A New Vacuum Pump..... 769
New Portable Magnetic Separator Outfit..... 770
Welding Defective Cores in Paper Mill..... 770
Personal 771
Digest of Electrochemical U. S. Patents..... 771
Book Reviews 772

"Fair Protection" for the American Chemical Manufacturer

The two papers by Mr. I. F. Stone and Mr. Maximilian Toch presented before the New York Section of the American Chemical Society last week and reported on page 710 of this issue, are more than mere papers. They are human documents of a most lively and important episode in the history of the American chemical industries. The quiet unassuming way of the authors typifies the quiet, unassuming way in which, since the beginning of the European war, the American chemist has gone ahead and has done things. Mr. Stone's paper is a record of a long string of big achievements. Mr. Toch's paper is the story of the creation of the new American barium industry.

As was said at this place last month, part of the present enormous activity in the chemical industries will stop when the war stops, since it has to do with war materials, but by far the most of the present activity will be lasting for the benefit of the whole country, if the American nation is willing that it be so. What is it that the chemical industry has a right to expect from the American nation? Nothing more nor less than a fair attitude of mind of the American nation toward the American chemical industry: a fair appreciation of its accomplishments and its aim, a fair recognition of the fact that chemical brains need capital for realization of their ideas and that capital needs fair protection. It seems right to discuss now more in detail what such "fair protection" would consist of.

In the first place, protection must be procured against unfair practices on the part of foreign competitors. But how shall such "unfair practices" be defined? The principal point is that when the war is over there will be great danger that the newly created chemical industries in this country be quickly destroyed by dumping on the markets of this country foreign products at a price below the selling price of the products in the producers' home markets. The American chemical industry has a right to expect from the nation's law makers that such methods of destroying dangerous competitors as are considered unfair and are now forbidden by law to Americans in the United States, should also be considered unfair and forbidden by law to importers from other countries. That is, the American chemical industry has a right to expect the enactment of an anti-dumping clause.

But whoever reads carefully Mr. Stone's and Mr. Toch's papers in this issue, or Mr. Stone's elaborate paper on the aniline dye situation in our issue of Oct. 1 (page 663) or Dr. Herty's opening address at the Exposition of Chemical Industries in the same issue

(page 695), or who endeavors to get exact knowledge concerning the situation from anybody who has a first-hand knowledge of the facts, will recognize that the enactment of an anti-dumping clause is not all that is needed. Tariff reform must be fairly and squarely considered. There are two main points which fairness requires in such consideration.

In the first place it must be strictly kept in mind that the American chemical industries face "a condition, not a theory." The abstract question of the desirability or undesirability of protective tariffs has been and will continue to be a fit subject of extended discussions by political economists, but it has nothing to do with the special concrete situation with which the chemical industries of this country and all who depend in some way on the products of the chemical industries are now confronted. The situation is such that academic discussions are almost out of place. But it may be said in parenthesis that if in these days any American chemist has an idle moment, he can find a great deal to satisfy his sense of humor in reading over the volumes of political economy which have been written on the theory of protective tariffs and contrasting the theory with the facts of the present moment. Just one example will explain what we mean. Chapters and chapters have been written on the question: Should industrial entities correspond to political entities? As a general academic question it is highly debatable. But it will be hard to find any sensible person of whatever party affiliations who has not learned from the experience of the past year the lesson that it is all important for the future of the American nation to be industrially self-contained. As Dr. Herty expressed it in his admirable presidential address before the American Chemical Society in Seattle, "in these days of rapidly shifting international relations the only sound and rational policy is national self-containedness." Likewise the old argument that a protective tariff, being a restraint, cannot have any positive virtue and cannot create industries, has absolutely no application to the present situation. The chemical industries which this country needed have been created during the past year by the pluck of the American chemist backed by American capital. Shall they be permitted to grow until they are firmly and permanently established? And what is necessary to accomplish this end?

This is the only real question. But to find the right answer, it is all important—and this is the second point to be kept in mind—that the whole consideration of the matter be taken out of party politics. The most promising and a decidedly practical way of accomplishing this was outlined by Mr. Howard H. Gross, president of the Tariff Commission League, in two addresses before the National Exposition of Chemical Industries in New York last month. As reported in our last issue (page 676), Mr. Gross argued that the net result of thirty years of "tariff tinkering" has been that nobody is satisfied, that business has been periodically upset, that hundreds of millions of money have been lost and millions of workers distressed. What is needed now is a really strong permanent non-partisan tariff commission of the highest personnel with long tenure of office, to make impartial investigations and recommend to Congress needed tariff adjustments on scientific principles. Whatever may be done in general, the conditions of the chemical industries require that something be done for their protection and that something be done very soon.

Shall the present vigorous growth of the American chemical industry remain but an episode in its history or shall it be the beginning of a new era? The American chemist has done his part faithfully and vigorously. It is for the American nation, as represented by Congress, to do the rest.

Non-Ferrous Metals During the War

Wide fluctuations in the price of a metal are usually ascribed to speculation, but the course of metal prices since the opening of the European war, although showing wide fluctuations, is not to be attributed to speculative influences. There is rather a dislocation of the ordinary movement of material whereby it becomes difficult to forecast the relation between supply and demand, while it is probably also the case that there have been important changes in the employment of metals for various war purposes, which have effected quick changes in the relation between supply and demand.

The non-ferrous metal markets certainly have pursued no orderly course in the fourteen months that have elapsed since the war opened. The first movement attributed to the war was a violent advance in tin, resulting in a doubling in the price before the war was a fortnight old. There was a veritable scare, due to the possibility that it would be found impossible to move tin from the Far East. A similar advance occurred in antimony, which advanced to three prices. Spelter, on the other hand, advanced because it was reported that large tonnages would be exported to England. The advances were practically all lost by the middle of September. Later there began a more orderly but still quite irregular advance in nearly all the metals. Lead, traditionally associated with war, was conspicuous by its failure to advance, though eventually it did advance in moderate fashion.

That there have been changes in the technique of war material manufacture is suggested by some of the market fluctuations. Spelter, which early rose and fell, and then toward the close of the old year began a definite and important rise, reached a very high point early in June, at more than five times its price of before the war, and since then it has been declining until lately it has sold at less than three prices. Aluminium, on the other hand, did not begin any sharp advance until last May, and the advance did not become sensational until September, about three months after spelter had started its sharp decline. Early this month it crossed the 50-cent line, truly a remarkable performance. The divergent movement between spelter and aluminium can hardly be ascribed entirely to manipulation or to a misjudging of market prospects by either buyers or sellers.

Regular consumers of the non-ferrous metals, entirely unaccustomed to such violent fluctuations as have char-

acterized the markets during the war, have not only been greatly inconvenienced but in many cases have suffered very severe losses. In many cases, probably, trade has been permanently lost. Unable to secure supplies of given materials at former prices, consumers of many products have been driven to the use of substitutes, and the substitute may in many cases find permanent employment.

The sheet-galvanizing industry has not yet been able to determine whether it has permanently or only temporarily lost a large proportion of its trade. It is estimated that since early in the year, when the advance in spelter forced the mills to ask much higher prices for galvanized sheets, the demand has ranged from 20 to 35 per cent of normal, the normal demand being nearly a million net tons a year. To an extent the consumptive requirements have been met by stocks in the hands of jobbers and manufacturing consumers, but there has doubtless been substitution in many instances, and whether the galvanized-sheet trade will ever regain its former proportions remains a matter of doubt. Prices lately asked by the mills for galvanized sheets are not considered sufficiently high to curtail consumption to any great extent, provided they were steadily maintained, but buyers are chary of purchasing, fearing sharp declines at any moment.

Iron Industry Making New Records

In the last two months of 1914 the iron and steel industry was in a state of unparalleled depression. The production of steel, in proportion to available capacity, was the smallest on record. Pig iron prices were lower than at any time in ten years, and steel prices lower than at any time in fifteen years. For November and December the United States Steel Corporation reported the lowest monthly earnings in its history, earnings at the rate of only $32,000,000 a year.

Never has the iron industry experienced so complete a change as that which has occurred since then, in approximately ten months. The production of both pig iron and steel ingots is now at a new high record rate, and there has been a continued and very important advance in steel prices, while in the past four months there has been a moderate improvement in pig iron prices. In all the past there can be found no precise parallel to this general movement. In 1908 production reached a relatively low rate, but prices did not decline correspondingly. In 1905, in 1909, and in 1912 there were sharp upward movements in prices, corresponding in general to the rate of the past ten months, but there was not a corresponding increase in tonnage outputs, as the percentage of idleness at the beginning of these various movements was not as great as was that at the beginning of this movement. Passing back to 1899 one finds more rapid price advances, spectacular as compared with those of recent months, but these occurred through demand having developed, in a period of low prices, to such an extent as to engage almost the full capacity of the industry. The price boom of 1899 followed two years each of which in its turn had broken all previous records in the production of pig iron and steel ingots, whereas the pig iron output in the second half of 1914 was less than two-thirds the record output for a half year.

In August certainly, and possibly in July, the steel works attained a new record rate in the production of ingots, and in September the country reached a new record rate in the production of pig iron, the new record pace in pig iron developing later than the new record in steel because the iron foundry trade is not busy and the production of steel-making pig iron had to proceed far enough to absorb the slack thereby produced.

Lake Superior iron ore shipments in August were heavier than in any previous August, and September in turn made a new record for that month, prospects being that the season's shipments will fall very close to the previous record, despite the slow movement early in the present season.

The current production of pig iron is at the rate of fully 36,000,000 tons a year, the best rate previously attained having been 34,000,000 tons a year, in February, 1913, while the greatest production in a calendar year was 30,966,152 tons, in 1913, while the highest production in two successive half years was 32,143,265 tons, in the twelvemonth ended June 30, 1913.

The current production of steel ingots, while it cannot be estimated closely, is known to be at a much greater rate, in proportion to pig-iron production, than has ever obtained before. While pig-iron production is easily at record rate, the consumption of pig iron in iron foundries is distinctly below rates that have obtained in several periods in the past, while in addition to this the output of steel ingots is particularly large in proportion to the pig iron charged. This condition arises in turn from two influences. There is a larger proportion of open-hearth capacity, in proportion to Bessemer, than ever before, and some of the open-hearth works are charging unusually large proportions of scrap as they are working largely upon war orders requiring altogether exceptionally great discards from the ingot. The pressure for steel is such that it is remarked the minutes, even the seconds, are counted against the open-hearth heat, and any practice that conduces to shortening the time is followed.

In striking contrast with the pressure for steel, as steel, is the relatively light operation of many of the finishing mills. There is always, of course, an excess of steel finishing over steel making capacity, and there is the further item that at the present time an altogether abnormal tonnage of forging steel is being produced. In ordinary years about half a million tons of forging billets are produced, but the rate of production at the present time is several times that amount.

The remarkable demand for steel is caused largely, of course, by the war, though the regular domestic demand is fairly good. The war is distinctly responsible for the fact that the change in conditions in ten months is so altogether unprecedented, for it was the war that caused the acute stagnation that characterized the closing months of last year, so that it has emphasized the contrast in each direction.

The Naval Consulting Board's First Meeting and First Recommendation

The Naval Consulting Board was created by Secretary Daniels, but eleven national engineering societies share with him the responsibility for its personnel. Its members, men of highest standing in the professions, serve without remuneration. At the first meeting held in Washington, D. C., on October 6 and 7, the Board organized and decided that the name should be the Naval Consulting Board, not Advisory Board. This is significant. The first recommendation of the Board is that of a large Research Laboratory for the Navy. This plan is in line with the present world-wide recognition of the value of scientific research not merely for the upbuilding of industries, but for the very independence of a nation. The Board is to meet every two months.

THE first meeting of the Naval Consulting Board was held in Washington, D. C., on Oct. 6 and 7, and was concerned largely with matters of organization, though one very important recommendation was made—that of the creation of a large research laboratory for the U. S. Navy.

The board was created by Secretary Daniels of the Navy, who appointed Mr. Thomas A. Edison chairman of the board, but left the selection of the 22 other members of the board to eleven national engineering societies. These eleven societies and their 22 representatives on the board are as follows:

American Institute of Electrical Engineers—
Frank Julian Sprague and Benjamin G. Lamme.
American Institute of Mining Engineers—
William L. Saunders and Benjamin B. Thayer.
American Society of Mechanical Engineers—
William LeRoy Emmet and Spencer Miller.
American Society of Civil Engineers—
Andrew M. Hunt and Alfred Craven.
American Chemical Society—
W. R. Whitney and L. H. Baekeland.
American Electrochemical Society—
Joseph W. Richards and Lawrence Addicks.
Inventors' Guild—
Peter Cooper Hewitt and Thomas Robins.
American Society of Aeronautic Engineers—
Henry A. W. Wood and Elmer A. Sperry.
American Society of Automobile Engineers—
Howard F. Coffin and Andrew L. Riker.
American Aeronautical Society—
Mathew B. Sellers and Hudson Maxim.
American Mathematical Society—
Robert S. Woodward and Arthur G. Webster.

The Board elected the following officers on Oct. 7:
Chairman, Thomas A. Edison.
First Vice-Chairman, Peter Cooper Hewitt.
Second (Acting) Vice-Chairman, W. L. Saunders.
Secretary, Thomas Robins.

Mr. Saunders was the acting chairman at the sessions of the Board which were attended by members of the Board only, with the exception of Mr. M. R. Hutchinson, who was present as Mr. Edison's "ear" and private assistant. Secretary Daniels conferred with the members repeatedly.

It was decided that the name, originally suggested as Naval Advisory Board, should be changed to Naval Consulting Board..

President Wilson received the Board on Oct. 6 at the White House and made the following address:

"There is very little that I can say to you, except to give you a very cordial welcome and to express my very great pleasure in this association of laymen with the Government. But I do want to say this:

"I think the whole nation is convinced that we ought to be prepared, not for war, but for defense, and very adequately prepared, and that the preparation for defense is not merely a technical matter, that it is not a matter that the Army and Navy alone can take care of, but a matter in which we must have the co-operation of the best brains and knowledge of the country, outside the official service of the Government, as well as inside.

"For my part, I feel that it is only in the spirit of a true democracy that we get together to lend such voluntary aid, the sort of aid that comes from interest, from a knowledge of the varied circumstances that are involved in handling a nation.

"I want you to feel, those of you who are coming to

LAWRENCE ADDICKS

THOMAS A. EDISON

LEO H. BAEKELAND

J. W. RICHARDS

WM. L. SAUNDERS

WILLIS R. WHITNEY

the assistance of the professional officers of the Government, that we have a very serious purpose, that we have not asked you to associate yourself with us except for a very definite and practical purpose—to get you to give us your best independent thoughts as to how we ought to make ready for any duty that may fall upon the nation.

"I do not have to expound it to you; you know as well as I do the spirit of America. The spirit of America is one of peace, but one of independence. It is a spirit that is profoundly concerned with peace, because it can express itself best only in peace. It is the spirit of peace and good-will and of human freedom; but it is also the spirit of a nation that is self-conscious, that knows and loves its mission in the world and that knows that it must command the respect of the world.

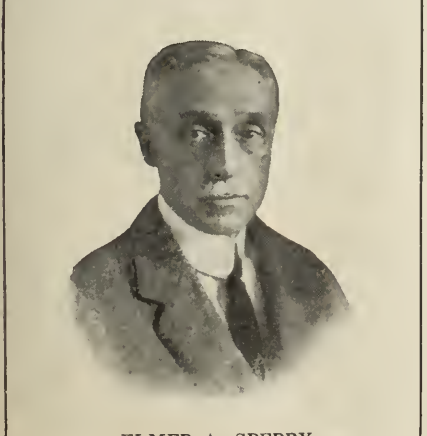
"So it seems to me that we are not working as those who would change anything of America, but only as those who would safeguard everything in America. I know that you will enter into conference with the officers of the Navy in that spirit and with that feeling, and it makes me proud, gentlemen, that the busy men of America—the men who stand at the front of their professions—should be willing in this way to associate themselves voluntarily with the Government in the task in which it needs all sorts of expert and serious advice.

"Nothing ought to be done in this by any single group of persons; everything ought to be done by all of us, united together, and I welcome this association in the most serious and grateful spirit."

It is interesting to reflect that in creating a Naval Consulting Board of scientists and engineers, Secretary Daniels had a predecessor in Napoleon (see Dr. Boekeland's paper in our last issue, page 677). But there is this big difference that as expressed in President Wilson's address the object of the Naval Consulting Board is to help in preparedness for defence, not for aggression. There is another difference in the democratic make-up of the Board in that eleven national engineering societies share with Secretary Daniels the responsibility for the personnel of the Board. The Board is made up of men who stand so high in their professions that they would accept no remuneration for serving their country.

By changing the name from Naval Advisory Board to Naval Consulting Board, the members have made it clear that they do not intend to force their advice unasked upon the Naval Board proper, but that they stand ready to place all their knowledge at the disposal of the Navy in consultation. This move has resulted in very cordial personal relations between civilians and navy men.

The first official recommendation of the Board has been the creation of a Naval Research Laboratory on such a scale that the first investment would be $5,000,000 and the annual operating expenses between $2,500,000 and $3,000,000. We are sure to interpret this recommendation correctly by saying that it is directly in line with the present world-wide recognition of the fact that scientific research on the largest scale is not merely the basis of the creation and evolution of industries, but is indispensable for national self-containedness and the very independence of nations. Germany has understood this truth for many years; Great Britain recognizes it now. The recommendation of the Board means that the United States should have a Naval Research Laboratory commensurate to the national importance of the U. S. Navy.



ELMER A. SPERRY

PETER COOPER HEWITT

B. B. THAYER

News from the Chemical Field

The Status of the American Chemical Industry and the New American Barium Industry

The first regular meeting of the session 1915-16 of the New York Section of the American Chemical Society (Dr. T. B. Wagner, chairman) was held on the evening of Oct. 8 in Rumford Hall, Chemists' Building. Two papers were presented which were exceedingly interesting by the manner in which they illustrated the enormous present activity in the chemical field.

Mr. I. F. Stone reviewed **"The Status of the Chemical Industries in the United States at the End of 1915."**

The production of *benzol* has become well established and benzol has become a serious competitor of gasoline as automobile fuel. About 100,000,000 gal. of gasoline are consumed by automobiles per year. Benzol has been carefully tested for automobile service and has been found to have 25 per cent more motive power than gasoline. The price has come down almost to that of gasoline, whereas before the war it was selling for two and three times that of gasoline.

Aniline dyes are produced to-day in the United States in three to four times the quantity produced before the war. By 1916 enough dyes will be manufactured in the United States to take care of the entire demand.

Carbolic acid is another important product now manufactured in this country in large quantities.

As regards *napthaline,* 2,500,000 lb. per year were produced before the war. This year 8,000,000 lb. will be turned out—almost covering the United States consumption of 9,000,000 lb.

Barytes: The imports in 1913 amounted to 40,000 tons. Since the war started Tennessee (Toch Brothers), Missouri and other States practically supply the demand. The present duty of 15 per cent must be increased if this industry is to continue in this country after the war is over.

Carbon Tetrachloride: Before the war only one-half of the CCl_4 consumed in the United States was made here. By 1916 all of it will be made here.

Acids: The general situation in the acid manufacture and consumption is very serious. We cannot make anywhere enough to supply the demand.

Alkalies and *bleach* industries show a great prosperity. We can take care of the entire American demand. Much of the Prussian blue is now made from soda instead of potash.

Oxalic Acid: Most of the acid consumed in this country is now made here.

In conclusion Mr. Stone said that the status of the American chemical industry as a whole is very satisfactory, and the industry in this country is very prosperous.

Mr. Maximilian Toch, partner of Toch Brothers, followed with an equally interesting and very encouraging paper on

"The Barium Industry in the United States Since the European War."—A little over a year ago there was no barium industry in this country. Germany and Austria have large mines of practically pure witherite, also cheap hydrochloric acid. It was impossible for American manufacturers to compete. This country does not possess similar rich mines and costs of labor, transportation, etc., are here much higher. Furthermore, the Governments abroad have subsidized the industry, enabling German and Austrian shipments to be unloaded here at $1.85 per ton (against crude United States barytes at $3 per ton).

However, barium salts have become an actual necessity in this country.

An important application of barium sulphate is in the gray paint of our battle ships; it resists the action of sea water and contains 45 per cent $BaSO_4$. Mr. Toch received the Government contract. To fill it, soon after the outbreak of the war, Mr. Toch went to Sweetwater, Tenn., and bought up the Gilman plant, now called the Durex Chemical Works.

Here at Sweetwater the mineral (barytes) occurs as a residual deposit, but not in such large masses as in Germany but in scattered small lumps. A large number of interesting slides of the deposits, mines, washers, furnaces, etc., were shown by Mr. Toch. Within a few weeks Mr. Toch expects to have the production increased to 32 tons of barium salts per day.

The barytes are mixed with coal and heated to bring about the following reaction:

$$BaSO_4 + 2C = BaS + 2CO_2$$

Fluorides, lead salts and other impurities prevent complete transformation into BaS or "black ash." This is subsequently fused with soda.

$$BaS + Na_2CO_3 = BaCO_3 + Na_2S.$$

The sodium sulphide by-product is sold to the dye manufacturers for making "sulphur black"; it competes easily with the Na_2S made by the reduction of Na_2SO_4 by coal. Barium salts are an important constituent of lithophone.

At present the salts are made in New York (on Long Island), but it would be cheaper to make them near the mines at Sweetwater, since zinc mines are close at hand there and labor and coal are abundant. It is interesting to note that Mr. Toch uses iron leaching tanks; FeS is formed on the surface of the iron which protects the metal underneath.

Mr. Toch emphasized that if the barium industry is put on a good solid business foundation with ample Government protection it will survive after the close of the European war. Industrial chemistry after all is 49 per cent chemistry and 51 per cent business.

In the discussion of the paper Dr. Doremus emphasized the importance of electric furnace methods for the reduction of barytes, and referred to the Jacobs process formerly carried out at Niagara Falls.

American Institute of Chemical Engineers

The winter meeting of the American Institute of Chemical Engineers will be held in Baltimore, Md., from Wednesday to Saturday, Jan. 12 to 15. The date selected is somewhat later than usual because the summer meeting was held late in August instead of June as is customary.

Excursions are being arranged to a number of chemical plants, Baltimore being a center of considerable industrial chemical activity. The experimental laboratories of Johns Hopkins University and the Naval Academy at Annapolis will also be visited.

Dr. John C. Olsen, Cooper Union, New York City, is the secretary of the institute.

Armco Iron Rust-Resisting Products and **Defeating Rust** are the titles of two interesting recent publications of the American Rolling Mill Co., Middletown, O.

Aluminium is the most abundant of all the metals. In the form of its oxide, alumina, it constitutes about 15 per cent of the earth's crust, according to the U. S. Geological Survey. Bauxite, however, from which aluminium is extracted by present commercial processes, is by no means plentiful, but known deposits are sufficient to make aluminium the important metal it is. The great future of this metal may lie in the perfection of a process whereby it can be commercially extracted from the unlimited deposits of alumina-rich clays and rocks in all parts of the world.

The Iron and Steel Market

The market pace in the steel trade has been rapid in the past fortnight. The scarcity of steel has been greatly accentuated, both by mills finding they were more oversold than they thought, and by demand broadening in several quarters, particularly in the line of railroad material.

The railroads are now definitely in the market for their steel requirements for 1916. They have already contracted for about 400,000 tons of rails, and with a further inquiry in the market the most vital needs of all the important roads will probably have been covered within another month. The railroads are not buying large individual tonnages of rails, their purchases being approximately equal to the average of the past two or three years, and their appearance in the market at this time is due simply to the fact that with so much rail mill capacity engaged in the rolling of large rounds for shells it is necessary to contract early to insure desired deliveries. Car buying is steady, although moderate. There is fairly heavy contracting for track supplies, at a time much earlier than usual.

There is a marked increase in the demand for steel from neutral countries, and exports of such material are likely to increase steadily from month to month, while the demand for steel from countries at war shows no abatement, covering not only munitions and material for munitions, but railroad and other material required really for war purposes, but somewhat less directly. Some South American countries are now taking more steel from the United States than they ever did in the past, marking a very decided improvement in this trade, as on account of industrial depression in South America the demand had decreased markedly during the twelvemonth before the war started.

Rates of Production

We estimate that at the middle of October pig iron is being produced in the United States at a rate of more than 36,000,000 tons per annum, contrasting with a previous maximum of 34,000,000 tons, reached in February, 1913. The steel interests have increased their pig-iron production by more than this amount, as the merchant furnaces are producing at a rate about 1,500,000 tons less than at their previous high record rate. We estimate the rate of production of steel ingots at between 38,000,000 and 39,000,000 tons per annum, against actual production of slightly more than 30,000,000 tons in each of the two best years on record, 1912 and 1913. The production of ingots is somewhat larger, relative to the production of pig iron, than normal, owing to the heavy cropping of ingots involved in the production of special steel required for war purposes. By reason of this heavy cropping of ingots, and by reason further of the heavy production of forging billets, also for the production of war material, the production of finished rolled merchant steel is an unprecedentedly small percentage of the total ingot tonnage.

Pig Iron

The pig-iron market has been practically stationary in the past fortnight. During the first six months of the year pig-iron prices were almost stationary, advances occurring in July, August and September averaging from $2 to $2.50 per ton in the different districts. The market the past fortnight has been distinctly less active than it was, on an average, during the first half of the year. The advances in recent months were due partly to sentiment, as steel prices were advancing, and as the slightly expanding demand required the blowing in of furnaces having higher costs than those already in operation. Now the pig-iron market awaits a fresh stimulus. There is ample production of merchant iron to meet all current requirements and as quite a number of merchant stacks could be blown in on short notice there is no uneasiness on the part of buyers. To cause another important advance in pig iron will require either a large increase in activity at gray and malleable iron foundries, or large buying of merchant iron by steel works, such as might, perhaps, be caused by their having been drawing upon stocks lately, or by some of their own furnaces being forced out of blast for relining. The steel works can hardly consume more pig iron than they have been consuming in the past two months. We quote: No. 2 foundry delivered Philadelphia, $16.25 to $16.75; f.o.b. furnace, Buffalo, $15.50 to $16; delivered Cleveland, $15.25; f.o.b. furnace, Chicago, $14.25 to $14.75; f.o.b. Birmingham, $11.50 to $12.50, the higher figure being for first half 1916; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $16; basic, $15; malleable, $14.50 to $15, depending on manganese specification; No. 2 foundry, $14.50 to $15, depending on delivery; gray forge, $14.25 to $14.75, depending on delivery.

Steel

The market for ordinary soft steel open-hearth billets has disappeared, and Bessemer billets, the market quotation for which has been made chiefly by reference to the market for open-hearth, has not developed a clear cut market, but the commodity can be quoted roundly at $25 to $26, f.o.b. maker's mill, Youngstown. Neither Bessemer nor open-hearth sheet bars are really a market commodity now, as sheet and tin mills are covered largely by old contracts and have such selling prices, apparenty dictated by the cost of their steel, that they could not afford to pay prices that would be asked for sheet bars, which normally command an advance over open-hearth.

The disappearance of the market for ordinary soft steel open-hearth billets is due to the large demand there has been for forging billets, for making large shells, and for analysis billets for rolling large rounds for smaller shells, generally about 3-in. The most common specification for steel for rolling such rounds is not over 0.04 per cent sulphur, 0.04 to 0.08 per cent phosphorus and silicon, say 0.20 to 0.30 per cent or 0.30 to 0.40 per cent, with carbon 0.32 to 0.42 per cent in the case of French and 0.47 to 0.57 per cent in the case of English. The carbon is, of course, very ordinary for a carbon specification, the sulphur is not really difficult and the phosphorus is particularly easy. The silicon merely requires the proper blast furnace Bessemer ferrosilicon addition. The cropping varies, from a total of 20 or 25 per cent to a maximum of 40 per cent, 35 per cent top and 5 per cent bottom. The cropping usually must be done from the ingot, requiring sawing, and the ingots must be chipped to avoid seams that would be dangerous—at the wrong time—in the thin shell which is ultimately produced. These specifications involve no problem, yet as high as $45 is being paid for the billets. Naturally the mills able and willing to produce such steel have no occasion to quote on ordinary soft steel billets, as buyers could not think of paying such prices as they would be disposed to ask.

While the demand for steel billets of this character is heavy, there is another condition making steel particularly scarce as a market commodity and that is that a number of steel mills made a curious over-

sight in selling against specifications involving heavy cropping, in that they neglected to observe that their output ratings were referable to their ingot-producing capacity, the rating therefore including the material that is cropped as well as the material that is sold, and if a mill can produce 10,000 tons of ingots in a given time it cannot crop 25 or 30 per cent of the ingots and still have 10,000 tons of material to apply on the sales contract. A number of mills find themselves oversold through neglecting to observe this arithmetical fact.

Finished Steel

Finished steel prices are steadily advancing, in one commodity or another. The basis for present advances in finished steel is not the specifically heavy demand for this finished product or that, but the general scarcity of steel. In the large mills making a variety of products very few departments are allotted steel to their rolling capacity. Thus the bar mills may be breaking their records, rolling 110 or 120 per cent of their rated capacities, and being given steel to do so because the orders for bars are in hand for a run of six weeks or perhaps several months, while the structural mills may be allotted only enough steel to operate at 60 or 70 per cent, the structural mills perhaps having specifications for operating four or six weeks at this rate. Upon the wire mills there is special pressure. They are operating at an overload, filled with specifications in the barb wire departments for perhaps three months, with heavy specifications for plain wire and specifications for perhaps four weeks of output in nails.

Bars, plates and shapes for early specification and delivery at mill convenience, have advanced from 1.35c. to 1.40c. in the past fortnight, and while a few weeks ago 1.40c. was freely quoted on first quarter contracts this figure is now quoted with reserve, and some mills are practically refusing to quote for first quarter.

Current quotations, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard section, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.40c.

Shapes, 1.40c.

Steel bars and bands, 1.40c., base; steel hoops, 1.50c., base.

Iron bars, 1.559c. to 1.609c., Philadelphia; 1.35c., Chicago; refined iron bars, 1.45c. to 1.50c., Pittsburgh.

Plain wire, 1.60c.; galvanized wire, 2.30c.; painted barb wire, 1.90c.; galvanized barb wire, 2.60c.; wire nails, $1.75 base.

Sheets, blue annealed, 10-gage, 1.60c. to 1.70c.; black, 28-gage, 2.00c. to 2.10c.; galvanized, 28-gage, 3.50c.; painted corrugated, 28-gage, 2.30c.; galvanized corrugated, 28-gage, 3.55c.

Tin plate, $3.10 to $3.20 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 63½ per cent off list.

Boiler tubes (less than carloads): Steel, 71 per cent off list; iron, 60 per cent off list.

Structural rivets, 1.60c.; boiler rivets, 1.70c.

The unfilled obligations of the United States Steel Corporation at the close of September are reported at 5,317,608 tons, representing an increase during September of 409,153 tons, against a loss in August of 20,085 tons. September shipments may be estimated at 95 per cent of rated capacity (at about 47,000 tons daily), the increase in obligations representing 35 per cent of capacity, so that the bookings appear to have been 130 per cent of capacity.

American Institute of Metals

The annual meeting of the American Institute of Metals was held at Atlantic City, N. J., Sept. 28 to 30 inclusive, in conjunction with the convention of the American Foundrymen's Association. The attendance was very good, the natural advantages of Atlantic City at this time of the year probably inducing a great number to enjoy the convention.

The tenth annual Foundry and Machine Exhibition which was held on Young's Pier as a part of the convention was opened on Sept. 25 and continued to Oct. 1. The exhibition was representative of the great progress of the metal working industries during the past few years. On Tuesday morning, Sept. 28, a joint session of the American Institute of Metals and the American Foundrymen's Association was held in the Greek Temple on Young's Million Dollar Pier.

The American Institute of Metals held its first independent session Tuesday afternoon at the Hotel Traymore. The paper by Gilbert Rigg and Henry C. Morse on "The Influence of the Impurities of Spelter on the Cracking of Slush Castings" brought out some discussion in which it was concluded that cadmium produces a hot short condition in zinc which renders it unfit for castings. Lead produces a bad effect also, in making heavy castings. Arsenic has little or no effect in the small amounts usually found. A paper on "Standard Test Specimens of Zinc-Bronze" was presented by Dr. H. S. Rawdon of the Bureau of Standards. Dr. G. K. Burgess read a paper on "An Investigation of Fusible Tin Boiler Plugs" which was abstracted in this journal Sept. 1, page 568.

On Wednesday morning the session was opened by a paper on "The Effect of the Present European War on the Metal Industries," by Thomas F. Wettstein. The discussion brought out the fact that a great number who had been using Lake copper were forced to experiment with electrolytic with the result that very few would go back to the use of Lake copper as long as there was such a wide difference in the prices. The subject of "sherardizing" was illustrated by a number of diagrams sent by the General Electric Company.

On Wednesday afternoon the session was given over to the discussion of aluminium and its alloys. A paper by Charles Pack on "Aluminium Die Casting a Commercial Achievement" discussed this important use of aluminium. A paper on "Melting Aluminium Chips" by Dr. H. W. Gillett discussed the difficulty, on account of a thin film of oxide on the chips formed when they were cut. Two commercial methods were given in detail. A paper by W. M. Corse on "Auminium-Bronze Alloys" took up the remarkable changes in hardness which can be brought about above 7 per cent of aluminium and discussed the commercial possibilities of these alloys. Other papers presented were "The Autogenous Welding of Aluminium" by E. V. Pannell and "The Manufacture and Use of Alumino-Vanadium" by W. W. Clark.

Papers presented at other meetings of the Institute included a paper on "An Acid-Resisting Alloy" by S. W. Parr. An alloy was found and described which would withstand the continued action of nitric acid without loss. Two papers on brass were read, viz: "Some Experiences with Brass in Civil Engineering Works" by A. D. Flinn, "The Failure of Structural Brass" by Dr. P. D. Merica. We reserve fuller accounts of a number of the papers presented for future issues.

At the business meeting of the Institute Mr. Jesse L. Jones of the Westinghouse Electric & Manufacturing Company was elected president succeeding Mr. G. H. Clamer. Mr. W. M. Corse of the Titanium Alloy Manufacturing Company was re-elected secretary.

The Range of Applicability of the Liquid Sulphur Dioxide Method for Determining Aromatic Constituents in Hydrocarbon Mixtures[1]

BY W. F. RITTMAN AND R. J. MOORE

One of the most convenient and widely used methods of separating the constituents of liquid mixtures is that based on differences of solubility in some reagent. To make this method effective it is necessary that these differences shall be considerable and that the solvent shall be easily removable from each of the two fractions after the extraction has been accomplished.

When used at sufficiently low temperatures liquid sulphur dioxide has the property of dissolving readily aromatic and unsaturated hydrocarbons and leaving unaffected the saturated paraffins and naphthenes. In addition, it is easily removable from hydrocarbons, either by evaporation or by washing with an aqueous alkaline solution.

On the basis of these properties Edleanu[2] has developed a commercial process for the refining of petroleum and also has worked out the details of a laboratory method of analysis. His problems were in the line of estimating aromatic constituents as impurities in ordinary petroleum mixtures and he records the obtaining of excellent results.

In connection with work on the production of aromatic hydrocarbons by the cracking of petroleum methods of analysis and separation were sought which should be reliable, accurate and convenient. Results of the major portion of these researches are recorded in another communication.*

The present note describes some experiments in which the liquid sulphur dioxide method was tried out with known mixtures. The results obtained were sufficient to indicate clearly the range of applicability as regards concentration of aromatics.

Experimental

Mixtures were made up which contained known proportions of aromatic and non-aromatic constituents. For the former was used a mixture of 16 per cent cymene, 42 per cent xylene and 42 per cent toluene. This mixture had a specific gravity at 15 deg. C. of 0.874 and a refractive index of 1.494. The paraffins were represented by a gasoline of specific gravity 0.720 and refractive index 1.400, which gave no coloration when treated with a mixture of nitric and sulphuric acids. The known mixtures were made up on a basis of percentage by volume.

The experiments here described were performed by a modification of the Edleanu method which seemed to be sufficiently accurate for present purposes. Apparatus consisted of a fifty cubic centimeter graduated tube equipped with well ground glass stop-cocks at either end, a jar to contain cooling mixture and a small tank of liquid sulphur dioxide. The apparatus is shown in Fig. 1.

The mixture to be tested was introduced into the graduated tube and the latter immersed in a cooling mixture of ice and salt. Connection was made with the sulphur dioxide tank by means of a length of heavy walled rubber tubing, the valve was opened and the gas allowed to distill over into the oil. After the latter became saturated, a second (lower) layer appeared which consisted of liquified sulphur dioxide, holding in solution the aromatics. The two layers were separated by running out through the lower stop-cock and the sulphur dioxide slowly boiled off until a temperature of 50 deg. C. was reached. This method of procedure undoubtedly was responsible for a certain amount of loss which could have been avoided in case it were necessary by the washing with aqueous alkaline solution recommended by Edleanu. Specific gravities and refractive indices were determined for the residues from both layers. Their quantities were of course measured.

The results of experiments with mixtures of varying composition are shown in Table I. It appears that with a concentration of aromatics not exceeding 25 per cent, separation may be obtained by the use of sulphur dioxide at temperatures in the neighborhood of — 20 deg. C. The separation was not, however, satisfactory at concentrations exceeding 15 per cent, as above this point there are no good figures for percentages and physical constants of the fractions separated. The matter of temperature once more was shown to be of great importance. As the two layer system, obtained in the graduated tube, is permitted to warm up the line of demarcation becomes blurred and finally disappears when temperatures in the neighborhood of 10 deg. to 15 deg. are reached.

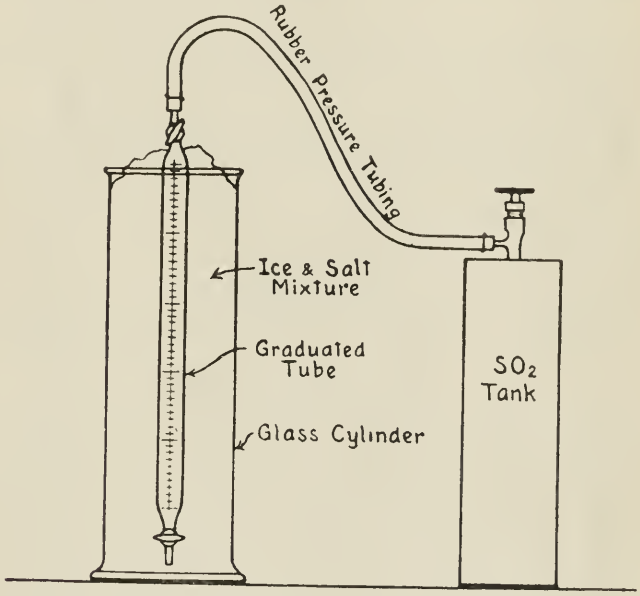


FIG. 1—APPARATUS FOR SULPHUR DIOXIDE SEPARATION

TABLE I.

SULPHUR DIOXIDE SEPARATION OF KNOWN MIXTURES

Constituents used:

Paraffin—A gasoline giving no coloration with nitric-sulphuric acid mixture. Specific gravity 0.720. Refractive index 1.400.

Aromatic—A mixture of 16 per cent cymene, 42 per cent xylene and 42 per cent toluene. Specific gravity 0.874. Refractive index 1.494.

Exp. No.	cc Mixture	cc SO_2	Temp. C., Deg.	Per Cent Arom.	Total Per Cent Arom. and Non-Arom. Recovered	Per Cent Arom. Separated
1	16.0	24.0	— 20	15.0	98.2	14.3
2	16.0	25.0	— 20	18.0	94.4	16.3
3	14.0	20.0	— 19.5	20.0	90.0	15.0
4	14.0	19.0	— 20	25.0	Hazy separation	
5	14.5	20.0	— 19.5	30.0	No separation	
6	12.5	18.5	— 20	50.0	No separation	
7	14.0	19.0	— 19	60.0	No separation	
8	14.5	19.5	— 20	67.0	No separation	
9	14.0	20.0	— 20	75.0	No separation	

COMPARISON OF PROPERTIES OF ORIGINAL AND SEPARATED HYDROCARBONS

Hydrocarbon Sample	Sp. Gr. Non-Arom.	Sp. Gr. Arom.	Ref. Index, Non-Arom.	Ref. Index, Arom.
Original	0.720	0.874	1.400	1.494
Exp. No. 1.....	0.722	0.870	1.410	1.491
Exp. No. 2.....	0.723	0.869	1.415	1.490
Exp. No 3.....	0.751	.....	1.425	1.485

[1]Published with the permission of the Director of the Bureau of Mines.

[2]Bull. Am. Inst. Min. Eng., Sept., 1914, page 2313.

*Rittman, Twomey & Egloff, Metallurgical and Chemical Engineering, October, 1915.

Edleanu records obtaining at —10 deg. separation with a mixture containing 40 per cent of aromatics. With the hydrocarbons used in the present experiments the limit seems to be much lower. Multiple extraction, as recommended by Edleanu, would undoubtedly improve results between the limits of 15 per cent and 25 per cent, but it is difficult to see how this device could help when a first extraction failed to obtain separation into layers.

Summary

1. It has appeared that although the liquid sulphur dioxide method works well for the estimation of small quantities of aromatics in hydrocarbon mixtures it is not applicable if the content exceeds a limit in the neighborhood of 25 per cent.

If it is desired to determine aromatics by this method when the concentration is greater, use must be made of the device of diluting with a pure paraffin mixture such as water white Pennsylvania kerosene. Diluting with an equal volume will bring mixtures containing from 25 per cent to 50 per cent below the limit of separation. Dilution with three volumes of the paraffin will take care of oils whose aromatic content ranges between 50 per cent and 100 per cent.

2. Temperature at which extractions are performed must be low, preferably in the neighborhood of —20 deg. C.

The experiments here described were performed in the laboratory of the Department of Inorganic Chemistry of Columbia University, New York.

Chemical Section of the Petroleum Division, U. S. Bureau of Mines, Pittsburgh, Pa.

Liquid Jets

A Study of a Phenomenon of Importance in Flotation and Cyanidation

BY C. TERRY DU RELL

The whole subject of flotation depends upon gas absorption. The mineral to be saved as a concentrate must have occluded sufficient gas to prevent its being wetted by the flotation liquid. Once wetted with the flotation liquid, its tendency is to sink as there can then be no surface tension effect tending to float it. The flotation liquid may be assumed in all cases to be water as it has been proven that no liquid except mercury has such great surface tension. Water will enter the pores of a solid from which all gas has been driven out and adhere to the surface so that the solid becomes as a part of the liquid so far as surface tension effects are concerned. That is, if there is a force of adhesion existing between the molecules of the water and the molecules of the solid, flotation cannot take place. If the particles be on the surface of the water, this truth is readily seen when an attempt is made to float them with say a Henry Wood type of machine, but it is not so readily seen when an attempt is made to float them by means of bubbles or froth if the particles be below the surface of the water.

Hereinafter then, only flotation of submerged particles will be considered. If a particle is to be floated by means of minute bubbles, these bubbles must be attached to the particle; or, if it is to be floated by means of froth, the particle must be attached to a bubble. The surface tension of a liquid film surrounding a gas bubble, being much greater than the adhesive force between a gas and a solid, holds the gas firmly inside the film so that attachment in this case between the gas and solid cannot take place. It is easily proven that gas, to be attached to a solid in a liquid, must be in a nascent state in the liquid. On being driven out, it will collect in the form of bubbles. It is therefore quite evident that, if the solid contain some of this gas, it will be a nucleus for the collection of these bubbles due to cohesive force existing between molecules of gas at the surface of the solid and molecules of gas in the liquid immediately surrounding the solid. Since air is readily soluble in water (especially the oxygen) and also since it is occluded by most solids, due especially to the chemical affinity of the oxygen, it is by far the most preferable gas for flotation as well as the cheapest, and will be hereafter the only one considered.

Due to the fact that air is soluble in oil and that oil is practically insoluble in water, it is readily seen that gas can be much easier attached to oiled mineral particles. Molecular attractions only being considered, the thinnest possible film of oil is all that is necessary. "Oil prevents the wetting of mineral particles" is evidently an erroneous statement since it is common practice to oil-coat the mineral particles while they are in the water. The particle contains gas and therefore can be oiled. Due to the cohesive force of the oil, a film may be formed which adds strength to the water film and prevents the bubbles from bursting so easily.

By the addition of an acid or an alkali to the water to form an electrolyte, an ionized condition is produced which creates a selective action of flotation due to occlusive power of at least some of the minerals being affected.

Role of Air in Flotation

After examination of all the different materials used in connection with flotation, it is seen to depend entirely on, first, dissolving air in preferably an electrolyte as well as in the ore and, second, the expulsion of this air. This all depends on Henry's law.[1] From this law it is readily seen that air may easily be expelled from either the electrolyte or ore particles[2] by heat or reduction of pressure.

It is evident that it makes no difference whether the gas be absorbed at high pressure and liberated by reduction to atmospheric pressure or absorbed at atmospheric pressure and liberated by vacuum. Naturally then the fundamental requisite for flotation is the production of a state whereby both water and mineral will absorb air. This eliminates any process in which air, dissolved at atmospheric pressure and temperature, is liberated by a vacuum, as such a process, necessarily limited to low altitudes, is crude and full of too many mechanical difficulties which make it unnecessarily expensive to operate. This has been the experience of plants operating by such a method.

According to the law of Henry, it would be possible, by varying temperature and pressure, to make water absorb its own volume of air since, for instance, at 10 deg. C. it is known to dissolve 2 1/3 per cent of its own volume at sea level. As an example, it would be quite easy to subject the water to say 90 lb. pressure per square inch or six atmospheres when, at the ordinary mill water temperatures of 10 deg. C., it would dissolve 15 per cent of its volume of air. As this requires some power, it is well to investigate the quantity necessary to be dissolved to effect flotation. That is, what degree of saturation is necessary?

As noted above, it is only the air that is driven out of solution or nascent air that can be used for bubble making or flotation. These bubbles, on coming to the surface, tend to burst, due to expansion, etc. Then the greater the pressure of the gas in the bubble the greater will be this bursting tendency. Therefore it would seem desirable to form these bubbles at com-

[1] At constant temperature, gas dissolved in a given volume of liquid varies directly as the pressure. Each gas is dissolved independently of all other gases.

[2] Cook's Chemical Physics. Solution of gases.

parative shallow depths in the water and with as little pressure as possible. In other words, mere supersaturation of the water with air near the water surface.

Supersaturating Liquids with Gases

A simple way to supersaturate water with air at atmospheric pressure is to beat it in with paddles or stirrers. The Minerals Separation Co. has patents describing this means. "Beating air into solution" does not well explain just what action takes place. To study this, take the simplest case of a single paddle, say a piece of wood partly submerged in water. Move it rapidly through the water. The instant the water is divided, a film of air forms on these division walls. As the water closes in again behind the paddle, this air film is taken into the interior of the water. Being a mere film, it is absorbed. The water, being already saturated with air, cannot hold any more so the excess must come out in the form of bubbles.

If there be paddles or blades on a shaft revolving rapidly below the surface of the water, a vortex is created and the water, on going down to take the place of that thrown out from the ends of the blades, carries air in with it as a film on the surface. It is readily seen that surface tension is the cause of this air being carried in and absorbed by the water. If the bubbles form fast enough, froth is produced, especially if there be sufficient material present to coat and toughen the bubbles.

This is a common method for getting air into solution and of every day occurrence. Eggs are beaten to a froth and the bubbles toughened with sugar. A small boy drags a stick rapidly through the water to see the bubbles in its wake. The water astern from a ship is white with the reflection of light from the air bubbles of supersaturation caused by the propeller. The surface tension at the crest of a wave, on "breaking," causes the air to be absorbed and given out as bubbles.

Another way of supersaturating a liquid with a gas has hitherto not been taken advantage of in flotation. Common occurrences of this are to be noted as well. On drawing water from a tap into a wash basin for instance, bubbles are seen to form and rise to the surface. Where does this air come from? If water from a hose be turned by means of a nozzle into a bucket some little distance away, a froth is formed. Fish in an aquarium rise to the surface for want of air. The attendant opens a jet of water fixed a short distance above the surface. This water shoots down into the aquarium, a stream of bubbles rise to the surface and the fish goes back to the bottom satisfied.

A stream of pulp is turned into a thickening tank from some little distance above, either directly or through a pipe straight down and below the surface and the millman is driven distracted by the froth that forms and causes a muddy overflow. It is then necessary to fit an interior ring as a barrier against the bubbles in order to obtain a clear overflow.

These phenomena are therefore worthy of investigation as air can apparently be taken into solution this way as well as with paddles or stirrers. This may be classified and defined as streams of liquid projected through a gas and into a liquid. The term liquid jet is applicable as it is a phenomenon of a jet of liquid as shown by the cited examples.

Phenomena of Liquid Jets

In investigating this. it would be well to first investigate the injection of a liquid into a gas. The liquid may be injected (1) vertically upward, (2) vertically downward or (3) at an angle. With a jet turned straight down, gravity is bound to accelerate the fall of the liquid. At some distance from the nozzle, the liquid will be traveling faster than that portion leaving the nozzle, due to this acceleration. This, it is seen, will tend to break the stream up into short cylinders and stretch the intervening liquid into long thin cylinders. Further acceleration will break these larger portions off. Surface tension, having rounded the edges previous to their breaking off, will immediately form them into drops and at the same time form smaller drops from the long thin cylinders in between. Thus there will be a falling succession of drops alternating large and small. The surface tension of the air film is so great that these small spheres are formed. Pictures have been taken showing this action in detail.

With the jet turned straight up, gravity retards the stream so the velocity becomes less as the distance from the nozzle increases. The whole stream is surrounded as before with an air film, the surface tension of which carries it along. When the gravity plus the weight becomes equal to the initial pressure, portions must be forced out sideways and spherical drops formed as described above. The surface tension of the surrounding air films prevent their re-uniting so that they will actually rebound from one another.

With a jet turned out at an angle (horizontal or inclined), gravity retards and pulls the stream down until portions are broken off to form spherical drops. The viscosity of a liquid tends to counteract this so that glass, for instance, can be spun or drawn out into threads.

The intensity of this surface tension effect may be shown by directing a jet of water onto an oiler or dusted surface when the globules of water will be held intact and roll the same as if they were enclosed in a solid substance when, in reality, they are only enclosed in a "skin of air."

The jet of liquid before breaking up was thus seen to be enclosed in a cylinder of gas, the surface tension of which caused it to move with the liquid and at the same velocity. The rush of air into a large nozzle to form this enclosing air cylinder may be readily felt by the hand. In other words, a jet of liquid turned into a gas does not merely slide through that gas or a cylinder of that gas but carries the "gas cylinder" along with it.

If the jet of liquid, passing through a gas, be turned into the surface of a liquid, the enclosing gas cylinder is evidently carried into the liquid and, if the liquids mix or are soluble in each other, the gas must be liberated. That is, the cohesion or adhesion, as the case may be, of the liquid jet for the liquid it has penetrated is sufficient to overcome the surface tension of the gas cylinder. The gas, being in such a thin film, is so finely divided it enters in between the molecules of the liquid in the intersticial spaces, and, if the liquid is not already saturated, remains there. A jet of gas entering a liquid, would, due to this surface tension effect, act the same as a jet of liquid entering a gas.

A simple way to prove that this gas cylinder goes into solution is to turn a jet of water into a vessel of water that has been boiled and cooled. On reheating, air will be expelled from the water in this vessel while none will be expelled from a similar quantity of water into which no jet has been turned.

When a liquid is entirely saturated with a gas brought in with a jet, supersaturation has the effect of producing nascent gas which collects in the form of bubbles. This fact is taken advantage of for flotation and will eventually be put to many other uses.

At the present time, this principle is used to a large extent for the hydraulic compression of air, where the surface tension causes the air film to be entrained and carried down a pipe of shaft to be liberated at the bot-

tom in a chamber under pressure. Frizell, although not recognizing this principle of air introduction with his air compressor design, does recognize the fact that it is not necessary to have a large number of small air inlet pipes at the intake. The simplest form is used for ventilating mines and, since oxygen is more soluble in water than nitrogen, the liberated air contains nearly 35 per cent oxygen against less than 21 per cent oxygen in the air introduced by a blower, for instance.

Importance in Cyanidation

It seems strange that this liquid-jet phenomenon has not been recognized before by many cyanide metallurgists since it has been the direct cause of many cyanide plant failures. Visit any old or modern cyanide plant and see the numerous jets of solution passing through the air and into a tank of solution. Pumps deliver streams here and there and through the air into tanks of solution or of pulp. Everything is supersaturated with air.

With sand leaching, this does not prevent operations being carried on, although, with some ores, an extra cyanide and lime consumption results. The millman simply remarks that the ore has a latent acidity, dumps in more cyanide and lime and lets it go at that. He does not bother with a reason for certain contained minerals being rapidly oxidized.

However, it is with the slime that big troubles occur. When the slime is very fine, and settlement and filtration difficulties are experienced, the millman, knowing it is not a crystalloidal slime, assumes that it must be a colloidal slime and that settles the question though not the slime. Simple logic this. It must be one of two things. Therefore, since it is not the one, it must be the other. The last few years, many cyanide metallurgists seem to think only of "the gel state" or "the sol state" and seem to have forgotten that a state of suspension can exist so that a pulp may only resemble a colloidal state.

This excess air coming out of solution is attached to even the smallest particles of slime as well as the larger particles. The larger ones can perhaps settle in spite of this buoyant tendency while the smaller ones may not show the slightest tendency to settle. It is a well known fact that settlement of the particles or of a precipitate takes place rapidly after the solution has been boiled and cooled. The only effect of the boiling is to drive out the air.

In many cases, when a solution of water stands until it appears perfectly clear, boiling and cooling will show an appreciable sediment on the bottom of the container.

It is certainly extremely difficult to thoroughly mix a pulp ready for filtration when some of it is floating, due to air bubbles, and the balance settles out readily. Much trouble is thus caused with the cake on a vacuum machine as well as in a press.

Plenty of trouble is caused in a cyanide plant when the bubbles are practically microscopic but great difficulty has been experienced at some plants where the bubbles were quite large and at a few where froth formed.

It seems doubtful if there is a single case of difficult slime settlement due entirely to a true colloidal condition as most pulp solutions are so supersaturated with air that they are more nearly ready for a flotation plant than they are for a cyanide plant.

Los Angeles, Cal.

Comparative Tests of Piston-Drill Bits is the title of the August, 1915, Bulletin of the University of Missouri School of Mines and Metallurgy. The authors are Prof. C. R. Forbes and L. M. Cummings.

Notes on Concentration at Nevada Consolidated Copper Co.

(Editorial Correspondence)

In common with other large Western producers of copper, the Nevada Consolidated Copper Company has been pushing work to the limit of plant capacity. The concentrator, which ordinarily has handled an average of 1000 tons per day in each of the eight sections, is now treating a total of over 10,000 tons per day. From 3 tons to 4 tons of water is required per ton of ore treated, fluctuating with changes in the character of the ore, so that the problem of securing an adequate water supply has made it necessary to resort to various means of recovering water that might otherwise go to waste. With some changes and improvements now contemplated, to be mentioned later, it is expected that the water requirement will be reduced and that the present supply will be ample.

At the present time the water piped from Duck Creek is supplemented by spring water pumped up from the valley, and some water is recovered from tailing ponds. Dorr thickeners, however, are playing the important part in the latest plan for water conservation, because they simultaneously recover a large volume of water and thicken a dilute slime for the flotation machines. The recovered water is used as a wash for concentrating tables. Some very slimy water, containing from 10 per cent to 15 per cent solids, is used at the smelter for granulating reverberatory slag. Eight 50-ft. Dorr thickeners have been in use at the mill for some time, and four more, 70 ft. in diameter, have been recently added.

Thickeners Operating in Earth Excavations

These are erected in the open on a bench of ground behind the mill; with only a small housing for the individual 3-hp. motors, and embody a number of interesting features conceived and executed by Mr. George C. Riser, mill superintendent. Wishing to reduce the cost of construction as much as possible, he dispensed with the usual wooden tanks and excavated a suitable opening in the earth in which to operate the thickener mechanism. The sides of the earth "tank" slope 45 deg. from the circumference toward the center, as shown in Fig. 1. Around the circumference a narrow bench is excavated to support a concrete collar that forms the overflow launder and supports the weir. The detail of this construction is shown in vertical section in Fig. 2. Bolts are embedded along the inner edge of the collar to secure pieces of wood for attachment of the weir. In the same manner pieces of pipe embedded along the uppermost surface form a support for an iron-pipe railing that surrounds the finished thickener. The trusses are supported on 12-in. I-beams resting on concrete

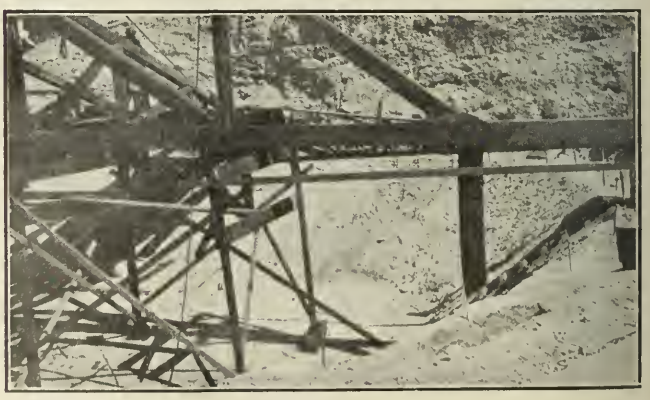


FIG. 1—EARTH EXCAVATION OF 70-FT. DORR THICKENER

piers. Fig. 3 shows a completed thickener operating in an earth excavation. This thickener gradually forms its own impervious walls and bottom of fine slime and no trouble is experienced from seepage. The 8-in. pipe for discharge of thickened slime is embedded in the bottom of the excavation and extends through the earth wall, issuing on the slope of the bench of ground in which the excavation is made. A similar pipe carries off the overflowing clear water.

The feed to these thickeners is carrying about 5 per

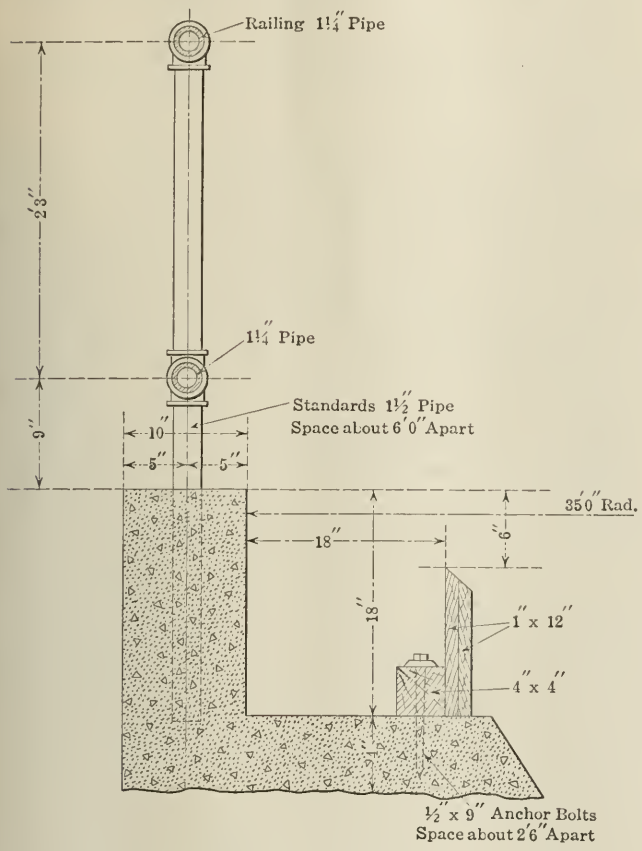


FIG. 2—DETAILS OF OVERFLOW LAUNDER

cent solids, and the discharge about 30 per cent. The only measurement of water recovery, made shortly after one of the thickeners was put in operation, indicates a recovery of 3 sec.-ft. for each 70-ft. thickener.

Changes in Grinding Practice

A number of changes are to be made in the present methods of grinding and concentrating which will greatly simplify the practice, increase capacity and recovery, and reduce the quantity of water required. For the present no change will be made in primary crushing, but rolls are to be abandoned for secondary crushing and fine grinding replaced with Hardinge ball mills. One section of the concentrator is to be remodeled for this experiment.

FIG. 3—COMPLETED THICKENER OPERATING IN EARTH EXCAVATION

In the present system the gyratory product is crushed in rolls, elevated and screened in trommels making two sizes for regrinding, 5/16 in. for return to coarse rolls and 3/16 in. to fine rolls. The product of the latter is elevated to 2-mm. trommels, the oversize of which is returned. The undersize flows to a four-compartment classifier. First and second classifications are treated on Wilfley tables, the tailings being reground. Third and fourth grades are similarly concentrated, the tailings being wasted. The classified overflow is thickened and treated by flotation in Janney machines. The reground Wilfley tailings are again classified into four products and treated on further Wilfley tables, all making final tailings except those handling the fourth classification, the tailings from which are treated on vanners.

In the section to be remodeled the rolls will be supplanted by Hardinge ball mills and the ground product elevated directly to classifiers. All grades plus 40-mesh will be treated on Wilfley tables as before, while the minus 40-mesh material will be treated by flotation. The tailings from the Wilfleys will be reground and also floated, vanners being eliminated in this section. The new plan offers obvious advantages over the old, both in the preparation of the ore and its treatment. The simplifying influence of flotation is seen in the elimination of some Wilfley tables and all vanners, and is the most important aspect of the proposed change. The changes in grinding will result in less handling of pulp and the use of less water.

Coal-handling machinery is in the August issue of the *Labor Savor*, a pamphlet by the Stephens-Adamson Mfg. Co., Aurora, Ill.

Sirocco Service, a pamphlet published by the American Blower Co., Detroit, gives many facts regarding the different uses of Sirocco Blowers.

Talc and Soapstone.—The United States produces more talc and soapstone than all the rest of the world combined, the 1914 production being 172,296 short tons, valued at $1,865,087.

Lump fluorspar for the manufacture of hydrofluoric acid showed an increase of 55.8 per cent in quantity and 91.3 per cent in value of sales in 1914 over 1913, according to U. S. Geological Survey.

Cyanides.—In the twelve months ending March, 1914, Canada imported 1,165,490 pounds of potassium and sodium cyanides and 166,901 pounds of yellow and red prussiate of potash.

Tin.—According to Mineral Resources of the U. S. there were no domestic tin ores smelted in the U. S. in 1914, though some tin concentrates were shipped from Nome, Alaska, to Singapore for treatment, and there was considerable agitation for the domestic smelting of both Alaskan and Bolivian tin ores. An increased output from Alaska may result in the establishment of a tin smelter on the Pacific Coast.

Primary Mercurial Resistance Standards.—The Bureau of Standards has just issued Scientific Paper 256, dealing with the construction of four standard ohms in the form of mercury columns in glass tubes, and the work involved highly accurate measurements. Comparisons of the four standards showed the average deviation of their individual values from their mean value to be less than one-one hundred thousandth of an ohm. England, Germany, France, Russia, Japan and the United States now have mercury standards of resistance which all agree to a high accuracy.

Thermal Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

The doctrine of the conservation of energy and the interconvertibility of its forms was well established about the middle of the last century, but the latter was well in its third quarter before any systematic effort was made to apply that doctrine to the blast furnace.

This was first done by Sir Lothian Bell, who had made in his works-laboratory countless experiments conducted with a degree of scientific skill and breadth of vision rare in that day. With the results of these and the data on thermal capacities, heats of reaction, etc., so carefully and laboriously determined by the physicists of various countries, particularly France, he prepared a heat balance of the furnace showing the quantity of heat developing and the amounts utilized and lost in various ways, which was the beginning of any comprehensive knowledge of the subject, for without a knowledge of the theoretical amount of heat necessary to bring about the desired reactions in the furnace it is impossible to say whether we are getting a reasonable efficiency from the fuel or not.

Since that time heat balances without number have been prepared and used to prove any contention that it might please the fancy of their makers to uphold, but frequently without carrying much conviction. The reason for this was that while taking careful account of the quantity of heat they ignored the quality factor, that is, temperature-head or intensity. It was as if a hydraulic engineer tried to figure the water-power obtainable at a given site by accurate and painstaking determinations of the quantity of water passing without any regard to the head, or an electrician were to try to figure the power of a given circuit from the amperes of current without respect to its voltage, or more accurately still as if a steam engineer tried to figure the power he could obtain from a definite quantity of steam without knowing the temperature, on which its pressure depends.

This condition is all the more curious because in the case of the other great application of heat, the steam engine, the importance of the intensity factor was worked out and stated in mathematical language many years before the doctrines of the conservation and convertibility of energy were discovered, and both of these were known and the theory of the steam engine was complete, virtually in its present form, about the time Sir Lothian Bell's work on the heat balance of the blast furnace was begun.

This theory of the steam engine was completely enunciated by two laws known as the First and Second Laws of Thermodynamics. These may be expressed for our purpose as follows:

1. The quantity of work produced by transformation of heat bears a definite and unchanging ratio to the quantity of heat transformed.

2. The proportion of any given quantity of heat which can be utilized for conversion into work depends upon the temperatures at which the heat is applied and discharged.

The first of these laws is simply a special form of the law of conservation of energy, and by substituting "chemical change" for "work" it would express the law of the blast furnace which Sir Lothian Bell and his followers understood. But that the blast furnace depended also upon a similar "second law" was totally beyond their knowledge, although it is just as important in this case as in that of the steam engine. This accounts for the failure of the elaborate calculations based on the first law alone, to explain many of the well-recognized phenomena of blast-furnace practice.

For instance, the introduction of the hot blast reduced the fuel consumption of soft-coal furnaces more than a half, although the heat of the blast introduced was only about 18 per cent of the total produced—a preposterous state of affairs viewed only in the light shed by the heat balance—and Sir Lothian Bell spent not pages, but chapters, in trying to prove that the benefit of the hot blast was strictly limited, and was, in fact, smaller than it was generally known in practice to be, because he could not make the facts square with his incomplete theory.

This is a subject with which I have had some connection in its later development, and it may not be amiss to treat this portion of it from a somewhat personal point of view.

The explanation of the hot blast given in Sir Lothian Bell's works did not seem to me to explain, and I had, moreover, been puzzled by the action of moisture in the blast, a subject treated by him in a similar way, because I had for a number of years been studying that subject carefully and keeping records of humidity in the engine room, which showed that the moisture present in summer above that present in winter was sufficient to account on that basis for only 4 or 5 per cent difference in fuel consumption, whereas the furnace records over a number of years showed 20 per cent difference. In 1899 it began to appear to me that there might be a critical temperature in the blast furnace above which some of the heat had to be supplied, and that as the range between this temperature and the theoretical combustion temperature was only a fraction of the latter, a change in the latter would have an effect on this range (which obviously measures the amount of such heat available), several times as great as the effect on the theoretical combustion temperature. I did not then know what the critical temperature was nor what controlled it, but calculations on this basis with assumed critical temperatures based on the best information obtainable as to the temperature inside of the furnace, seemed to show a better agreement with the facts than did Bell's figures, and this idea grew in strength.

In 1901 a "Lunette" optical pyrometer was procured and observations of temperature made through the tuyeres, and in every other way thinkable, to determine what the critical temperature really was, because as long as it was only assumed it could be arbitrarily chosen so as to bring results which would agree with practice, but which would mean nothing.

The results of these observations revealed the fact that there was a critical temperature, that it was controlled exclusively by the free-running temperature of the slag, and that this temperature for the furnaces under observation was about 2750 deg. Fahr. A totally different investigation revealed the fact that the result of the removal of the moisture from the blast was identical in principle with that of the hot blast, and that its effects could be figured in exactly the same way.

Calculations of heat available above this critical temperature of 2750 deg. under different conditions of blast temperature and humidity agreed with the relative coke consumption under those conditions so well as almost to arouse suspicion of the possibility of self-deception, but the same principle seemed to work quantitatively under the most diverse conditions and to explain many facts not adequately explained before, and I became convinced it was correct.

The idea is so simple that it seemed almost sure that it must have occurred to some one else long ago, and I made the best search I could through the blast-furnace literature of four countries to see if this were true without finding a trace of it anywhere.

I wished to obtain certain patents founded on this principle so kept it secret for three years, until the summer of 1904.

At that time the patents desired were allowed and the preparation begun of a paper to set forth this new theory of blast-furnace action.

In that autumn Mr. James Gayley published his paper describing the actual results he had obtained at the Isabella Furnaces by the application of his system of drying the blast.

This was most fortunate for me, as it supplied authentic data strongly confirmatory of the new theory which were totally inexplicable by the old, and would, as I supposed, hasten the acceptance of the former, for it never occurred to me that the publication of Mr. Gayley's results would arouse any doubts of their correctness or any other sentiment except admiration for the solution of a problem of which all furnacemen must be aware and for which they must desire a solution. As a matter of fact, the announcement of Gayley's results set the whole metallurgical world into a furore, many furnacemen and near-scientists refused to accept the results, and even went so far as to question the correctness, not to say truthfulness, of the furnace records.

My paper entitled "Notes on the Physical Action of the Blast Furnace" was submitted to the American Institute of Mining Engineers in the autumn of 1904, soon after Mr. Gayley's paper was read, but was held up in the secretary's office for almost a year. It was, however, presented orally at the Washington meeting of the Institute in May, 1905.

It was with great trepidation that I attacked the old theory as so incomplete as to be utterly misleading, expecting to be savagely criticized for my temerity and to see efforts made to riddle the new theory, and it was correspondingly surprising to see it accepted without a single protest by American furnacemen and metallurgists, because it explained Mr. Gayley's results. Thus instead of his facts being used to sustain the new theory, as would surely have been expected, the new theory was quite generally accepted because it sustained Mr. Gayley's facts.

It is proper to say that while the acceptance of the new theory seems as far as one can judge to be quite general in America, there are many indications that it has made little or no impression in Europe, and it seems, as far as I can gather, to have been definitely rejected in Germany.

After the lapse of ten years, during which this theory has been used as a tool for the investigation of many of the problems of the blast furnace, the original presentation seems to me to be as good as anything I can offer now, though it is no more than proper to state that it has been presented in slightly different form by various other furnacemen and metallurgists, some of whom seem to regard it as entirely their own.

The original presentation from the paper above mentioned (Trans. A. I. M. E.) follows.

THE RESULTS OF HEATING AND DRYING THE BLAST

The explanations offered by writers on the blast furnace to account for the economic effect of heating the blast are non-quantitative and therefore inadequate. The following paragraphs, translated from Ledebur[1], give perhaps the best example:

"When, later, systematic investigations of the influence of the hot blast began to be made, the surprising fact was frequently observed that by heating the blast more fuel could be saved than was necessary for the production of the heat brought in by the hot blast. Moreover, it was very generally observed that the top of the furnace became cooler the more the blast was heated.

"The two phenomena bear a close relationship to each other. The furnace requires, for each kilogram of iron produced, a certain quantity of heat, and the production of this heat, as has been mentioned earlier, is the primary purpose of the combustion of the fuel by the blast. Each kilogram so burnt furnishes a definite quantity of gas which ascends into the furnace.

"But now, if a part of the required heat, instead of being produced by the combustion of carbon, be brought in by the heated blast, the resulting quantity of gas must be as much smaller as corresponds to the saving in fuel; the smaller quantity of gas gives up its heat more quickly and completely to the counter-current of descending solid material than does the larger quantity of gas resulting with the cold blast.

"The heat is accordingly more advantageously utilized in operating with hot blast, and, by this means, a secondary saving in fuel is made. The consequence of this is that the gas leaves the furnace in a cooler condition, and the top temperature falls."

Bell's explanation is not very different and no more satisfactory.

A simple explanation, which affords a basis for quantitative estimates in close accord with the actual facts, is afforded by considering the temperature at which a part of the total heat must be applied.

In the application of heat to the generation of power, it was realized more than a century ago that the temperature of application was of equal importance with the quantity of heat; and it seems remarkable that, in metallurgy, attention is rarely paid to the temperature at which the heat must be applied for the accomplishment of a given purpose, and that quantitative data bearing on this subject are practically unknown.

Calculations of the total quantity of heat imparted to the furnace by the combustion of 1 lb. of carbon, have often been made; and in a few cases calculations have also been made as to the maximum temperatures obtainable under various conditions, but if there have ever been any calculations as to the quantities of heat available at different temperatures, I have never heard of them.

The point of view from which this subject should be considered differs so slightly, but so radically, from the common one, that the distinction is not easy to make clear, but may perhaps be best approached by the conception of a "critical" temperature. It may be said without reservation that for every set of furnace conditions there is a certain critical temperature above which only, certain necessary operations of the process can be carried out. It is not necessary to know what the operations are, and no attempt will be made to enumerate them here, further than to say that they probably comprise the removal of the final traces of oxygen from the ore, the formation and subsequent superheating of the cinder, and the melting, carbonization and superheating of the iron—"superheating" being used in the sense of heating above the point of fusion.

Given the existence of such a critical temperature, it is easy to see that where the heating is done by direct contact with the combustion and its products, as in the bosh of a blast furnace, the only heat available for performing the operations which must take place above the critical temperature is the portion left after deducting the amount necessary to raise the products of combustion to that temperature. Or, to state the proposition in another way, if all the heat developed by combustion passed into the products of combustion, there would be available for the work of the hearth only that portion, the removal of which would suffice to reduce the products of combustion themselves to this critical temperature.

It is obvious that the nearer the critical temperature is to the theoretical temperature of combustion, the smaller will be the quantity of such available heat. If

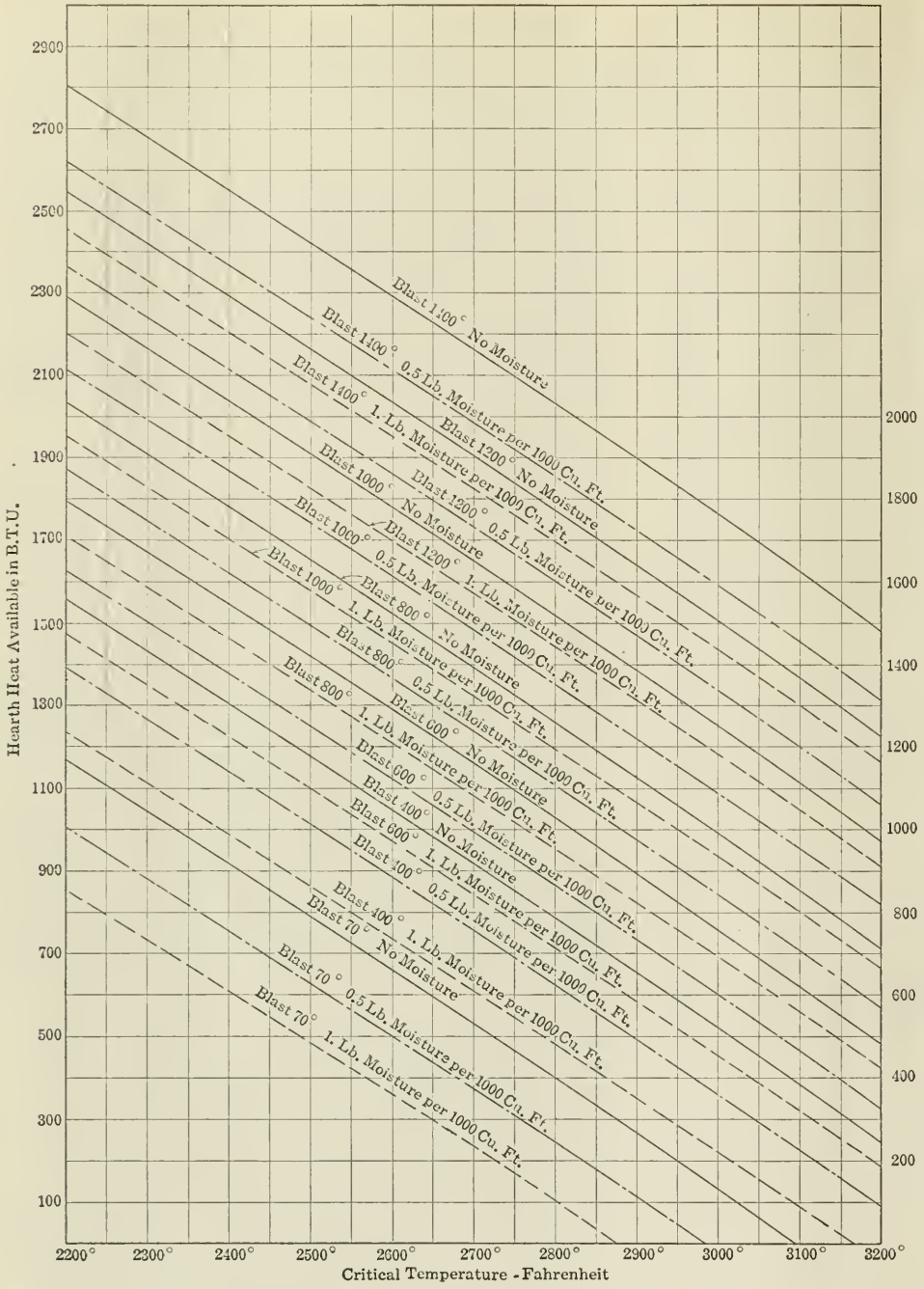

Hearth Heat Available in B.T.U.
Critical Temperature - Fahrenheit
Blast 1400° No Moisture
Blast 1400° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1400° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 1200° No Moisture
Blast 1200° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1200° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 1000° No Moisture
Blast 1000° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1000° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 800° No Moisture
Blast 800° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 800° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 600° No Moisture
Blast 600° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 600° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 400° No Moisture
Blast 400° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 400° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 70° No Moisture
Blast 70° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 70° 1. Lb. Moisture per 1000 Cu. Ft.

FIG. 1—HEARTH HEAT AVAILABLE PER POUND OF COKE, COUNTING 0.85 LB. OF FIXED CARBON ACTUALLY BURNED IN HEARTH, WITH DIFFERENT CRITICAL TEMPERATURES ALSO DIFFERENT BLAST TEMPERATURES AND DIFFERENT MOISTURE CONTENTS IN THE BLAST

the critical temperature is, say, four-fifths of the theoretical combustion-temperature, then the available heat is only one-fifth of the total; and while the other four-fifths are useful for other purposes, they are lost for those under consideration.

The critical temperature varies in the same furnace with varying conditions, but for certain conditions it was determined to be about 2750 deg. Fahr., as a probable average, and results obtained from calculations made on this basis were in such close agreement with the results, that the series was extended to cover other conditions, namely, two other critical temperatures, and varying quantities of moisture in the blast.

Such calculations are extremely simple and involve no uncertain assumptions, the method being as follows:

The combustion receives heat from three sources: the heat of combustion of carbon to CO; the heat brought in by the blast, and the heat brought in by the fuel. The latter may reasonably be assumed to be brought up to the critical temperature by the gas leaving the bosh, as the heat exchange is a true counter-current one, and the contact is intimate.

The heat brought in by the coke is therefore $2750 \times 0.21 = 577.5$ B.t.u., the heat of combustion of 0.9 lb. of carbon is $4450 \times 0.9 = 4005$ B.t.u., and the heat brought in by the air at 70 deg. Fahr. (cold blast) is $5.22 \times 0.2375 \times 70 = 86.8$ B.t.u., a total of 4669.3 B.t.u.

The products of combustion are 4.02 lb. of nitrogen and 2.1 lb. of CO; to heat these to 2750 deg. requires respectively $4.02 \times 0.2438 \times 2750 = 2695.2$, and $2.1 \times 0.2479 \times 2750 = 1431.6$ B.t.u., a total of 4126.8 B.t.u., which deducted from 4669.3 leaves 542.5 as the available heat above 2750 deg.

Now assume the blast to be heated to 1000 deg.; the heat brought in by the blast becomes 1241.8 B.t.u., or 1155 B.t.u. more than before; the other items of heat brought in remain the same, as do those of heat removed by the products of combustion; consequently, the available heat is increased by this amount, which is a little more than twice the original amount, making the available heat in this case 1697.5 B.t.u., or more than three times that in the previous case.

A series of calculations were made on this basis for different blast-temperatures, and also for different critical temperatures; these are given in graphic form in Fig. 1.

It is perfectly obvious that the higher the critical temperature the less the available heat will be for a given blast-temperature, and vice versa.

The modification introduced by variable moisture content in the blast is not quite so simple, but not in the least complicated.

By way of preliminary it may be explained that the unit of moisture in the blast here adopted is 1 lb. per 1000 cu. ft. of air, since the latter is the unit of blast measurement. There being 7000 grains in a pound the commonly-used unit of grains per cubic foot may be reduced to that here used by simply dividing by 7.

(*To be continued in issue of Nov. 1*)

Cryolite.—No cryolite is produced in the United States, the entire supply used in this country being imported from Ivigtut, an Eskimo hamlet on the southern coast of Greenland, free of duty.

Metallurgy at the International Engineering Congress—II

San Francisco, September 20 to 25, 1915

In our last issue accounts were given of the papers and discussions on iron and steel and on copper. In the following we will first report two papers on copper omitted in our last issue on account of limitations of space and then give an account of the symposia on gold and silver, zinc, lead, and fuels.

Copper

(*Concluded from page* 662)

The Metallography of Copper was the subject of a paper by Prof. WILLIAM CAMPBELL of Columbia University. The author discusses the effect of copper oxide on copper and the effect of cold work and hot work on the structure of copper.

To show the effect of copper oxide on copper the author reviews the work of Heyn and Slade and Farrow. The freezing point of copper, 1084 deg. C., is depressed by the addition of Cu_2O, progressing until we reach a minimum of 1065 deg. C. and 3.5 per cent Cu_2O. A further increase in Cu_2O raises the freezing point of the mixture.

The effect of cold work on the structure of copper is to draw out the grains of metal, and the greater the reduction the more the grains are drawn out. The reason for the increase in strength and decrease in ductility is matter of dispute. The "amorphous theory" has gained support. It holds that (a) polishing produces a film of amorphous metal as the surface; (b) when a metal is strained, the slip-lines and slip-bands are covered with a film of amorphous metal, which is less dense and much harder than the crystalline variety; and (c) where the crystals of a metal meet, thin films of residual liquid metal will remain under circumstances which render them incapable of crystallizing, so that they form films of amorphous metal as an intercrystalline cement.

In studying the effect of hot work, the first thing noted was that the Cu_2O of the eutectic was drawn out into long strings of rounded globules. The structure, after different degrees of reduction, resembled that of annealed metal. While the grains became progressively smaller they showed no elongation because the heat was sufficient to cause a rearrangement of the grain.

According to Faust, the crystallites in electrolytic copper arrange themselves parallel to the lines of the current. Electrolytic copper, like worked copper, develops twinning planes when annealed, indicating the presence of internal stress.

Boronized Cast Copper was the subject of a paper by Dr. E. WEINTRAUB of the General Electric Co., Lynn, Mass. The author discusses the theory and practice of the use of "boroflux" for producing cast copper of good mechanical properties and high electrical conductivity. Numerous references to the same subject may be found in the files of this journal.

Boroflux is defined as a material containing boron in a state of oxidation below that of boric anhydride. Such a material takes up oxygen and reduces oxygen-containing compounds. In this reaction the boroflux is transformed into boric anhydride which, being fluid at the temperature of the reaction, comes to the top of the metal, carrying in solution metallic oxides, particularly cuprous oxide. Boron suboxide and boron carbide are generally used, the suboxide being preferable. Three-quarters of one per cent is usually added. An average conductivity of over 90 per cent is regularly obtained. The efficiency of boroflux in deoxidizing copper that has been remelted a number of times is shown in the following table. A.B. indicates the average number of bends; R. indicates the resistance offered by test bar to the bend, given in percentage, assuming virgin copper to be 100 per cent.

	A. B.	R.
Virgin metal	1515	100%
First heat	850	97
Fourth heat	334	96
Boron suboxide	2007	103

The Coolidge tube has been used for making x-ray photographs of metal that has been treated with boroflux, in comparison with untreated metal. The photographs show the porosity of ordinary cast copper and the solidity of copper cast with boroflux.

Gold and Silver

The symposium on gold and silver, which had been prepared and edited by C. W. MERRILL, was the subject of discussion in the session of the morning of Friday, Sept. 24, CHARLES BUTTERS presiding.

A Coarse Crushing Plant of 1000 tons capacity was the subject of a paper by G. O. BRADLEY. The author stated that the equipment and arrangement of crushing plants is now receiving the same attention which was formerly devoted only to other parts of the reduction works. Manufacturers are now producing complete lines of machines suitable for special type of ores. The author outlined the design of a plant for dry crushing a thousand tons of ore of average hardness to ¼ in. in size, using electric power, concrete-steel construction, gyratories, rolls and automatic balanced skips, instead of bucket elevators, giving an estimate of costs and detailed drawings.

Mr. Bradley's paper developed some discussion on the relative merits and the proper use of jaw and gyratory crushers. Prof. Robert H. Richards stated that in his opinion gyratory crushers were specially adapted for large central plants and jaw crushers for secondary work. But the recent construction of the Traylor jaw cushers, 5 x 7 ft., may necessitate a change of this opinion. Crushing practice is now in a period of change.

Crushing and Grinding.—The trend of recent practice in crushing and grinding for cyanidation is outlined in this paper by L. D. MILLS and M. H. KURYLA. Large-scale operations, such as described in the foregoing paper by G. O. Bradley, are in a class by themselves and not adapted to the ordinary cyanide plant. Primary crushing is usually done in two stages: first a jaw crusher breaking from run-of-mine to 6 in., and then cone crushers to reduce this material to 2 in. The Symons disc crusher is a recent machine which is giving good results in crushing from 4 or 6 in. down to 1 or 2 in. This machine is good on hard, brittle ores, but not adapted to wet, sticky ores. Undersize must be eliminated from the feed. Typical costs of coarse crushing and conveying are given below:

Goldfield Consolidated, Nev., crushing and conveying	$0.046
Belmont Milling Company, Nev., crushing and conveying	0.068
Commonwealth Mine, Arizona, crushing and conveying	0.079
Hollinger Gold Mines, Porcupine, crushing and conveying	0.113

Fine crushing or coarse grinding covers reduction from 1½ or 2 in. to 0.25-in. aperture. The term to be used depends on whether the energy is applied by impact or attrition or both.

The gravity stamp crushing by impact is probably used in 95 per cent of the cyanide plants of the world. In spite of its unquestioned disadvantages, it continues in favor. There is a tendency in American and Canadian practice to adopt the ball mill, and it is the authors' belief that few, if any, new stamp mills will be built on the American continent.

The economic limit of battery-screen aperture in modern plants is considered to lie between 0.15 to 0.4 in. This statement applies either to American and Mexican all-sliming practice, 70 per cent or more through 200-mesh, or to Rand practice, 95 per cent through 65-mesh.

Stamp mill practice has reached its highest development in South Africa. The Nissen single stamp has been received with some favor there, showing one-third greater capacity, per pound of falling weight, and an equal gain in efficiency over the ordinary gravity stamp. Of the six new mills built on the Rand since competitive trials were made, however, only one proposes to adopt the Nissen stamp. In modern Rand plants the

Stamp Milling Data

Plant	Tons Milled 24 Hr.	Number of Stamps	Running Weight	Discharge Aperture	Hp.-Hr. P. T. Milled	Stamping Cost, Cts. P. T. Milled	Sizing	
							% −100 (0.0055 In.)	% −200 (0.0029 In.)
Mexico Silver Mill	1000	60	1450	0.371	4.8	10.0	....	14.0
Nipissing	245	40	1450	0.334	12.1	23.8	20.3	16.7
Belmont	500	60	1200	0.131	7.2	20.7	28.3	19.5
Silver Peak	500	120	1050	0.023	13.8	31.4	54.0	40.0
Homestake	4500	1020	850	0.022	11.0	20.4	80.0	60.0
Hollinger	585	60	1400	0.263	8.6	16.0	....	15.0
Porcupine Crown	150	20	1000	0.250	6.0	14.0	....	15.0
Liberty Bell	485	80	750	0.041	7.8	19.1	54.0	46.0

cost of stamping does not exceed 20 cents per ton; the average for the district in 1913 was 29.3 cents for thirty of the large plants.

Tube-mills have now been universally adopted for final grinding to a finished product. Classification for the elimination of finished material from the tube-mill discharge is a matter vital to the efficiency of the mill and has received close attention. Cone classifiers with diaphragms a few inches above the apex are preferred on the Rand where coarse grinding is employed. In America the Dorr, Akins, Ovoca and Esperanza classifiers are used, the tube-mills being in closed circuit.

Tube-Milling Data

Plant	Tons Milled 24 Hr.	No. Tubes	Dimensions of Tubes	Hp.-Hr. P. T. Milled	Cost P. T. Milled	Sizing Final Product	
						% −100 (0.0055 In.)	% −200 (0.0029 In.)
		6	5 ft. x 16 ft.				
Mexico Silver Mill	1000	6	5 ft. x 20 ft.	10.8	22.0	98.0	75.0
Nipissing	245	4	6 ft. x 20 ft.	44.6	50.0	100.0	100.0
Belmont	500	7	5 ft. x 18 ft.	16.8	40.9	99.0	72.3
Silver Peak	500	1	5 ft. x 18 ft.	2.4	2.6	64.0	50.0
		2	5 ft. x 14 ft.				
Homestake	4500	2	5 ft. x 18 ft.	0.5	1.2	87.0	66.0
Hollinger	585	6	5 ft. x 20 ft.	16.0	18.8	100.0	90.0
		1	5 ft. x 16 ft.				
Porcupine Crown	150	1	4 ft. x 20 ft.	5.7	36.0	100.0	90.0
Liberty Bell	485	3	5 ft. x 22 ft.	4.3	7.7	87.0	73.4

The authors note that the efficiency of the closed circuit has been questioned, but add that the contentions against it are not borne out in practice. As to moisture in tube-mill feed, 38 to 40 per cent has been generally accepted, and is probably correct for mills discharging within 6 in. of the central axis; but for mills with peripheral discharge, higher moistures will be found advisable. The proportion of tube-mill capacity to stamp capacity has been increased, and costs have been lowered as more work has been thrown on the tube-mill. It is possible that ball and tube-mills in series may supplant the stamp. Various substitutes for pebbles are being investigated, such as hollow cast iron or steel balls, and special polyhedron shapes. The Marathon or rod mill also has been tested with favorable results. Tube-milling costs in the newer plants on the Rand are about equal to stamp-milling costs; 18 to 20 cents per ton milled.

The use of stamps, Chilean mills and tube mills for stage crushing and grinding at the Goldfield Consolidated is unusual, but productive of low cost of operation. Stamps weigh 1050 lb., crushing through 4-mesh screen; 6-ft. Chilean mills have 30-mesh screens; tube-mills are 5 ft. by 22 ft. Following are costs per ton milled:

	Stamps		Chilean Mills		Tube Mills	
Labor	$0.039		$0.018		$0.014	
Supplies	0.041		0.041		0.065	
Power (232 hp.)	0.054	(210 hp.)	0.047	(357 hp.)	0.087	
	$0.134		$0.106		$0.166	

Power consumed by stamps, Chilean mills and tube mills.....22.5 hp.-hr. per ton milled
Total combined cost for stamps, Chilean mills and tube mills..$0.406 per ton milled

Chilean mills are used at the Portland mill, Cripple Creek, for final grinding where a fine product is not required. Six-ft. Akron Chilean mills run at 36 to 41 r.p.m., using 2.5 to 3 tons of solution per ton of ore. Steel consumption per ton of ore ground is 0.797 lb. gross and 0.692 lb. net. Power consumption per ton of ore in coarse-crushing department is 1.86 hp.-hr. and in Chilean mills, 13.26 hp.-hr., or a total of 15.12 hp.-hr. Following are cost data.

	Coarse Crushing, per Ton	Chilean Mills, per Ton	Total, per Ton
Power (at 0.842c. hp.-hr.)	$0.0199	$0.1118	$0.1317
Labor (operation)	0.0318	0.0179	0.0497
Labor (repairs)	0.0103	0.0039	0.0142
Supplies	0.0284	0.0482	0.0766
Total	$0.0904	$0.1818	$0.2722

Dry crushing in ball mills is still retained at Kalgoorlie, the data for No. 5 and No. 8 mills, respectively, being as follows: Size, 7 ft. 6 in. in diameter by 3 ft. 10 in. long, and 8 ft. 10 in. by 4 ft. 6 in.; screen areas, 70 and 100 sq. ft.; speeds, 25 and 23 r.p.m.; power consumption, 25 and 60 hp.; capacities, 40 and 95 tons per day, the feed being about 2½ in. and the discharge through 28-mesh screen containing from 40 to 50 per cent minus 200-mesh; steel consumption per ton milled varies from 0.4 to 0.7 lb.; average cost of ball-milling, $0.50 per ton milled.

Wet crushing ball mills are coming into favor with excellent results. They run smoothly and are free from the noise produced by stamps. Recent tests on an 8-ft. Marcy mill showed that when operated in closed circuit on 4-in. maximum feed, the finished product may be kept under 48-mesh if desired. Steel consumption was 0.75 lb. per ton crushed, and power consumption about 12 hp.-hr. per ton.

Griffin mills and grinding pans, once widely used, are now rarely installed in new plants.

In the discussion of the paper Mr. Charles Butters predicted that steel balls would displace pebbles for tube milling, as they would permit the use of shorter tubes with smaller diameter, running at a higher speed, with a consequent reduction in first cost and in operating cost. One pound of steel balls is equivalent to three to five pounds of pebbles.

Solution of Gold and Silver.—In this paper by M. H. KURYLA, on the solubility of gold and silver in cyanide solutions and the methods of treating ores to effect the dissolution of those metals, the author covers an extensive subject in small compass. The paper is already so condensed that abstracting is difficult. An effort is made to give typical examples and costs of treatment from different parts of the world. On the chemical side it is pointed out that the classical equation of Elsner,

$$2Au + 4KCN + O + H_2O = 2KAu(CN)_2 + 2KOH,$$

so generally accepted as representing the final reaction, is inadequate as a guide to the consumption of cyanide in the treatment of complex ores. The equation calls for 1.51 units of gold or 0.83 units of silver per unit of KCN. This relation is closely approximated in the treatment of many silver ores, but with gold ores a consumption of 20 of KCN to 1 of gold is considered satisfactory and 40 to 1 is more common.

The strength of cyanide solution for silver ores will probably average 4 lb. KCN per ton, and for gold ores, 1.5 lb. Average chemical and mechanical loss of cyanide will average 2 lb. for silver and ¾ lb. for gold ores. Sand leaching plants have contacts of from four to seven days, while the time of contact for slime in gold ores is about 8 hr. and in silver ores 48 hr. Heating solutions has been of benefit in silver ores, increasing dissolution by an ounce or two at a cost of from 10 to 25 cents per ton.

Amalgamation is an important accessory process to cyanidation, particularly in recovery of such coarse gold as may retard or escape dissolution in cyanide. As practised at the average plant it costs between 5 and 10 cents per ton, and the plate area is about 2 sq. ft. per ton milled. On the Rand the plate area ranges from 0.25 to 2 sq. ft. per ton milled, and the mercury consumption about 0.1 oz. At the Homestake, with inside and outside amalgamation, the plate area is about 11 sq. ft. per ton milled, with a mercury loss of 0.13 oz.

Concentration is another accessory process, practised for (a) shipment of high-grade concentrates to smelters; (b) recovery of lower grade concentrates for local cyanidation; and (c) removal of concentrates for finer grinding and subsequent return to the mill pulp.

CYANIDATION OF CONCENTRATES

Plant	Daily Production in Tons	Assay Ozs. per Ton Au.	Assay Ozs. per Ton Ag.	% Extraction Au.	% Extraction Ag.	KCN Cons. p. t. Concentrates lbs.	Cost per Ton of Concts. Grinding	Roasting	Dissolution	Acid Treatment	Filtering	Precip. and Refining	Total
A—Goldfield Cons., Nev.	55	6.58		98.53		7.	0.33	0.82	2.34	0.77	0.30	0.18	$5.68
B—Alaska Treadwell	75	2.92		96.5		2.3	0.57		0.78		0.22	0.81	2.81
C—Esperanza Mexico	1	22.68	54.2	99.4	95.8	6.0							4.85
D—Waihi, N. Z.	17	5.6	63.3	96.3	93.5	20.0							6.25
E—Geldenhuis Deep, Transvaal		16.0		98.75		3.3	3.65		2.67				6.32
F—Oriental Cons., Korea		2.2		93									2.87

Wet desulphurizing is accomplished at the Nipissing mill by grinding a complex arsenic-antimony-silver ore in 0.25 per cent NaOH solution and tube-milling with aluminium ingots and agitated in tanks containing aluminium sheets. The cost amounts to 48 cents per ton.

The standard systems of cyanidation, in order of prevalence, are slime agitation, sand leaching and filter slime treatment.

For slime agitation the ore is first thickened to a dilution of 1.5. Thickening is done in various forms

COMPARATIVE AGITATOR DATA

M.—Bottom Drive Mechanical. P.—Pachuca. D.—Dorr.
Sp. Grav. of Pulp = 1.326 (L:S = 1.5:1)
Power at $5.00 per hp. per month.
Labor at $3.00 per 8-hr. shift.

Type	Size, Feet	Capacity, Dry Tons of Slime	Total Erected Cost	Erected Cost per Ton of Capacity	Power per 100 Tons of Slime	Total Operating and Repair Cost per Ton of Slime per 24 Hrs.—500 Ton Plant
M	30x12	134	$2395.00	$17.87	D—3.0 hp.	D—1.8 cents
D	30x12	134	2510.00	18.73	M— .2 hp.	P—2.3 cents
P	15x45	102	1935.00	18.97	P—6.9 hp.	M—2.4 cents

Agitator Requisites	Violence of Agitation	Total Operating Cost per Ton	Regulation of Amount of Air for Aeration	Freedom from Choking or Settling	Ease of Starting After Shut-down	Adaptability to: Varying Pulp Conditions	Adaptability to: Continuous System of Agitation	Adaptability to: Selective Agitation	Operating Simplicity	Minimum Loss in Mill Height
In order of preference	P	D	M	D	P	P	D	D	P	D
	D	P	D	P	D	D	P	P	D	M
	M	M	P	M	M	M	M	M	M	P

The cost ranges from 5 to 15 cents per ton, averaging perhaps 10 cents. The following table gives condensed data on cyanidation of concentrates. The details of the processes have been given in the technical press.

Roasting is practised prior to cyanidation when the ore contains tellurium, arsenic or antimony, with which the gold may be intimately associated, either physically or chemically, the object being to liberate the gold for contact with cyanide. This is practised most extensively at Kalgoorlie, and to some extent on Cripple Creek telluride ores and on the graphitic ores of the Ashanti Goldfields. It is also practised on the concentrates at Goldfield, Nev. At Kalgoorlie the cost is about 65 cents per ton when using Merton or Edwards furnaces. Hearth area per ton of ore roasted in 24 hr. varies from 17 to 29 sq. ft. The cost of roasting Cripple Creek ore at the Portland mill in Holthoff and Pearce furnaces is 62.85 cents per ton. Chloridizing-roasting in the Holt-Dern furnace costs 51.5 cents per ton, including 35 cents for salt and 4.6 cents for coal dust.

of tanks, but the Dorr continuous thickener is favored. An average of 6 sq. ft. of settling area is allowed per ton of granular slime, and 10 to 15 ft. for flocculent material. Capacity may be greatly increased by the use of submerged trays in the same tank. Power requirement of a 30 ft. by 12 ft. Dorr thickener running at 1/5 r.p.m. is ¼ hp., and the operating cost about 1 cent per ton.

In agitation the trend is toward continuous operation. Four types of agitators are in use, one of which, the pump transfer system, is used mainly on the quick settling slime of the Rand. The other three systems are the mechanical, pneumatic and a combination of the two. The mechanical type has paddle-arm stirrers; the pneumatic uses compressed air in a central air-lift, as in the Brown or Pachuca; the combination uses both mechanical and pneumatic agitation, as in the Dorr.

The following figures on the cost of dissolution by slime agitation are merely numerical averages of compilations from representative plants in various parts of the world. The cost of dissolution includes thickening, agitating, proportionate pumping, supervision, cyanide, lime and lead salts.

	Cost of Dissolution	Cost of Filtration or Decantation Precip. and Refining	Total
Average gold ore	$0.29	$0.25	$0.54
Average silver ore	0.83	0.42	1.25

Sand leaching is practised most extensively on the Rand. Cost figures from 10 Rand plants in 1912, show the following averages:

Total cost of sand treatment per ton of sand (including classification, collecting, treating, precipitating, refining and residue disposal), ranging from 37 to 45 cents, average	39.8 cents
Average extraction on $3.17 sand heads	79.8%
Average extraction in recent sand plants	89.5%

At the Homestake the cost for sand leaching is 17.8 cents per ton; at the Pittsburgh Silver Peak, 23.5 cents. Itemized costs for the Rand and Homestake are:

Cost of Sand Treatment per Ton of Sand

Rand		Homestake	
Labor	6.54 cents	Superintendence	1.06 cents
Assaying, sampling	0.32	Assaying	0.48
Lime	0.56	Neutralization	1.54
Transferring, discharging	8.62	Transportation	0.17
Cyanide	7.23	Classification	1.18
Precipitation	1.56	Treatment	8.59
Zinc shavings	1.28	Precipitating and pumping solutions	1.18
Clean-up, smelting	2.92	Refining	0.38
Sodium bisulphate	0.94	Heating	0.51
Miscellaneous supplies	2.30	Miscellaneous	0.81
Water	1.60	Repairs	1.88
Power and lights	6.48		
Miscellaneous	0.59		
Total	40.94 cents	Total	17.78 cents

Direct treatment of slime in filters is practised at the Homestake and at the Pittsburgh Silver Peak. The cost at the former is 18.38 cents per ton and at the latter 26.3 cents.

In the discussion which followed, J. C. Clennel mentioned the bad effect of an oxidizing roast on silver extraction. C. W. Merrill cited a case in which after the roast a 15 per cent lower extraction was obtained than on raw ore. G. H. Clevenger mentioned the same effect was produced by natural surface oxidations of silver ores, also containing manganese dioxide. Charles Butters spoke of the importance of the dilution of pulp on silver extraction. He is now working on new problems of cyaniding flotation concentrates.

Filtration of Slime.—In this paper by L. D. Mills, all processes for separating and recovering valuable metal-bearing solution from slime are considered. This is one of the most vital points in cyanidation. The various methods considered are: Thickening, vacuum filtration, pressure filtration, continuous decantation and intermittent decantation.

The use of the Dorr continuous thickener has become almost universal. Discharges as low as 33 per cent and up to 60 per cent moisture can be obtained, varying with the nature of the slime. On the Rand, with colored labor at $0.75 or less per day and power at $5.50 per hp.-month, it is still found economical to retain intermittent settlers. The cost of thickening will vary from $0.005 to $0.02 per ton of ore milled, depending on local conditions and scale of operations.

Among vacuum filters, the author considers the Butters by far the most widely used. Others are the Moore, Oliver, Portland and Ridgeway. Average cost of operating Butters filters on the Rand is given as $0.065 per ton filtered. The caking effluent is worth $2 per ton, and the dissolved loss amounts to $0.05 or less. At the Goldfield Consolidated, the cost of operating a Butters filters is $0.05 per ton. Dissolved loss is $0.06. Other Butters operating costs are:

McNamara, Tonopah	150 tons silver,	$0.237 per ton filtered
Montana-Tonopah, Tonopah	146 tons silver,	0.230 per ton filtered
Loretto, Pachuca	700 tons silver,	0.07 per ton filtered
Flores, Guanajuato	160 tons silver,	0.06 per ton filtered
Dos Estrellos, El Oro	750 tons gold,	0.075 per ton filtered

A 1000-ton filter at the Victoria mill, Australia, has an operating cost of $0.0996 per ton filtered. The caking effluent averages $4.60 gold and 1.72 oz. silver, with dissolved loss at $0.048 gold and 0.02 oz. silver. Other Moore filter costs are:

Hollinger, Porcupine	600 tons gold,	$0.103 per ton filtered
Liberty Bell, Colorado	430 tons gold and silver,	0.099 per tonfiltered
La Blanca, Pachuca	300 tons silver,	0.105 per ton filtered
San Rafael, Pachuca	400 tons silver,	0.110 per ton filtered

Note.—These costs do not include royalty.

The Oliver and Portland are revolving-drum continuous filters. Operating cost of an Oliver filter at the Mexican mill on the Comstock is given as $0.072; dissolved loss, $0.09, largely in silver. At the Portland mill, the operating cost of Portland filters is $0.08 per ton filtered; dissolved loss, $0.07, mainly in gold.

Among pressure filters the author discusses the Dehne, Merrill, Kelly and Burt.

Dehne presses were used in the early days of cyaniding, particularly in Africa and Australia. They are adapted to treatment of granular or roasted slime; with amorphous slime the cakes must be thin and the washing is erratic. The average cost of operation in Australia may be taken as $0.25 per ton filtered, with $0.10 per ton additional for residue disposal.

The Merrill automatic sluicing filter press combines the washing efficiency of the plate-and-frame press with convenient wet discharge of cake. When the ore is comparatively granular the press is filled solid full; when amorphous material is present, it is advisable to fill the chambers not quite full. The capital cost of the filter is high, but it has an unusually high washing efficiency and low operating cost. At the Homestake the cost is $0.028 per ton, including labor, power and supplies.

The Kelly enclosed-leaf pressure filter shows an operating cost of $0.25 per ton at the 250-ton plant of the Tigre Mining Co., in Sonora.

The Burt revolving filter is restricted in use to granular slime. At El Oro operating cost was $0.049 per ton. The washing efficiency is stated to be 98 per cent.

Continuous counter-current decantation with Dorr thickeners is becoming a popular process, especially for small plants. The mechanical loss of cyanide is one of the factors that limits its use without filters. Actual operating cost is very low; at the Porcupine-Crown the cost of dissolution and counter-current washing approximates $0.30 per ton.

The author concludes that the handling of slime has reached a development where no further radical changes are to be expected. The mechanics of the various operations will be modified to suit special conditions, and there is always a possibility of reducing capital cost.

In the discussion which followed, Mr. Butters disagreed with the author's conclusion that no more radical changes in slime treatment may be expected. Mr. Butters anticipates that other forces than gravity may be

advantageously employed in the future for settling slime, such as electrical and centrifugal forces.

Precipitation of Cyanide Solutions.—The author of this paper, G. H. CLEVENGER, has gone thoroughly into the history and present status of the processes of precipitating precious metals from cyanide solutions.

CLASSIFICATION OF VARIOUS METHODS OF PRECIPITATION, USED AND PROPOSED

ELECTROLYTIC	(a) Iron anode; lead cathode; low current density; adherent deposit.			
	(b) Peroxidized lead anode; tin plate cathode; high current density; non-adherent deposit.			
	(c) Peroxidized lead anode; lead plate cathode; high current density; adherent deposit.			
	(d) Indirect electrolytic processes have only been investigated experimentally.			
CHEMICAL	Gaseous	Only example; possibly occluded gases in charcoal.		
	Liquid	Sodium sulphide (proposal for precipitating silver cuprous salts in acid solution).		
	Solid	Non-metallic	Charcoal	
		Metallic	Sodium	In form of amalgam, generally produced by electrolysis
			Aluminum	Shavings; Dust
			Zinc	Discs; Shavings; Dust

Electrolytic precipitation by the Siemens-Halske process was developed in South Africa to cope with low-grade solutions resulting from slime treatment. These solutions were not successfully precipitated on zinc. Later the introduction of the lead couple and a drip of strong solution made zinc precipitation satisfactory, and electrolytic precipitation declined and finally was abandoned. The latter process was used also by Charles Butters in San Salvador, Mexico and Nevada, but finally abandoned as zinc precipitation became better understood and improved. The following table gives the essential features of the electrolytic precipitation as practised in the past at various plants:

Process	Location	Number of Plants	Anode	Cathode	Current Density per Sq. Ft. Anode Amperes	Voltage	Metals in Solution	Remarks
Siemens-Halske	Rand, South Africa	20	Iron	Lead foil	0.03 to 0.06	4 to 8	Gold	Used alone
Butters-Andreoli	Minas Prietas, Mexico	1	Peroxidized lead	Tin plate	0.30 to 0.55		Silver, copper, gold	Used alone
Butters-Andreoli	San Sebastian, Salvador	1	Peroxidized lead	Lead plate	1.00 to 1.20	3 to 3.5	Copper, gold, zinc	Followed by zinc shavings
Butters-Andreoli	Virginia City, Nevada	1	Peroxidized lead	Aluminium plate	0.25	2.87	Silver, copper, gold, zinc	Followed by zinc shavings
Butters-Andreoli	El Rayo, Mexico	1	Peroxidized lead	Copper foil	1.20		Silver, copper, gold, zinc	Preceded by zinc dust

Charcoal precipitation is briefly discussed and the principles of aluminium precipitation are given. This latter process has been described in this journal, August, 1914, page 511.

COST OF ZINC SHAVING PRECIPITATION

Name of Plant	Type of Ore	Size of Compartments, In.	Cu. Ft. of Zinc per Ton of Solution Precipitated per 24 Hr.
San Rafael, Pachuca, Mexico	Silver-gold	33x33x30	
Loreto, Pachuca, Mexico	Silver-gold	36x48x30	0.75
Dos Estrellas, El Oro, Mexico	Silver-gold	30x30x24	0.65
El Oro Mining & Railway, El Oro, Mexico	Gold-silver	36x48x24	
Guanajuato Consolidated, Guanajuato, Mexico	Silver-gold	36x48x18	0.40
Guanajuato Reduction & Mines Co., Guanajuato, Mexico	Silver-gold	48x48x30	1.06
Divisadero, San Salvador, Central America	Silver-gold	24x36x18	0.54-0.81
Golden Cycle, Colorado Springs, U. S. A.	Gold	48x24x24	0.56
Tonopah Extension, Tonopah, Nev., U. S. A.	Silver-gold	30x34x26 36x34x30	0.93

Zinc precipitation is discussed under the heads of zinc shavings, wafers and dust. Numerous illustrations are given to show the manner of applying these methods, and considerable space is devoted to the preparation of zinc shavings. The Merrill zinc-dust process is described in detail.

Data on zinc-dust precipitation at the Homestake covering a period of one month are given as follows:

Plant	Heads	Tails	Pounds Zinc Dust per Ton of Solution	Cost of Precipitation per Ton of Ore Treated
No. 1 sand	$2.94	$0.018	0.173	$0.0123
No. 2 sand	2.77	0.034	0.174	0.0109
Slime	1.19	0.028	0.160	0.0165
Average on whole ore	1.87	0.026	0.165	

In refining, preliminary acid treatment of the precipitate has been found unnecessary in most cases where silver predominates, but is still adhered to in the majority of cases for gold precipitate.

The oil-fired tilting-crucible melting furnace has now largely replaced the earlier types of stationary-crucible furnaces, thus making the melting operation much less laborious, as well as considerably reducing its cost.

The Tavener method of refining, involving the melting of the precipitate in a small reverberatory furnace with various fluxes and lead, followed by cupellation, is still in general use in South Africa, but has not gained ground in this country.

The Homestake method of refining, involving acid treatment and briquetting with lead flux, followed by melting and cupellation in the ordinary English cupel furnace, as well as the treating of all the by-products in a small blast furnace, is used by a few American plants.

The melting of the precipitate, briquetted with the proper fluxes, in a small blast furnace, followed by cupellation of the lead, has been found of advantage when dealing with a large volume of low-grade gold precipitate. Losses from dusting, which might appear to be the chief objection to this method of melting, are claimed to be insignificant when a proper flux system is provided. This method of melting is more economical than either the Tavener or Homestake practice.

The most simple and satisfactory method of converting the high-grade precipitate which is obtained, by proper manipulation, from ores in which silver predominates is to melt the precipitate directly, with the minimum proportion of flux, in the tilting type of furnace.

In the discussion of this paper E. H. Simonds referred to the precipitation of low-strength cyanide solutions. He said there was no difficulty if both solution and zinc are perfectly clean. Mr. Butters said that aluminium dust is useful for silver solutions, but offers no advantage for gold.

Zinc

In the Friday afternoon session, in which E. B. BRADEN presided, the symposium on the metallurgy of zinc, arranged and edited by WALTER R. INGALLS, was first taken up.

Some main points in the economics of the metallurgy of zinc was the subject of a paper by WALTER R. INGALLS. The effect of the European war will be to produce even more radical changes in the zinc industry than were in progress when the war began.

The introduction of the Wilfley table in 1896 was an historic event in the zinc industry, for it made possible a better separation of the mixed ores requiring fine grinding. Another important step in the metallurgy of mixed ores was the introduction of the Wetherill system of magnetic concentration, followed by Blake's system of electrostatic concentration. The climax has been reached in the successful use of flotation at Broken Hill.

The development at Broken Hill had many important consequences: it standardized smelting practice in Belgium and Germany; compelled those smelters to go on a zinc-lead basis; showed that mixed ores could be profitable, and resulted in similar development elsewhere in the world.

During the last 50 years there have been three types of zinc smelting (the earlier English and Carinthian processes having disappeared), which are known as the Silesian, Belgo-Silesian, and Belgian. In recent years, the Belgo-Silesian method has become known as the Rhenish, and this has shown a strong tendency to displace the Belgian process in Belgium and an even stronger tendency to displace the Silesian process in Silesia. The reasons for this are discussed in the metallurgical treatises, of which zinc smelting has recently acquired a rich literature. They may be summarized as a superior economy, as compared with the Belgian furnace; and, in Silesia, a change in the character of the ore which causes this method to be better adapted than the Silesian furnace. In the United States, the method of smelting is essentially the Belgian, which has been modified to conform to peculiar conditions.

Another basic factor in the zinc industry which is causing radical change is the manufacture of sulphuric acid from the roasting of blende. This has long been practised in Europe, and is now coming into vogue in America. Every smelter of blende east of the Mississippi River is now making acid.

The author sketches briefly a comparison of European and American practice, and gives the economic reasons for the differences. The following figures are offered as broad generalizations to show the differences in the art as practised here and abroad. They mean that the Europeans, with the aid of better furnaces and superior technical direction, are able to smelt more refractory ores and yet extract a higher proportion of the valuable metals. Such economies as America has effected have been chiefly in the handling of material, which, in zinc smelting, is a relatively small part of the process.

"Per ton of raw sulphide ore, the American smelter uses about 2 to 2½ tons of coal and two or three man-days of labor; and extracts about 84 to 88 per cent of the zinc that is in his ore; if he treats lead-bearing ore, he may recover 50 to 60 per cent of the lead.

"The European smelter uses about 1¼ to 1¾ tons of coal and 3 to 3½ man-days of labor; and extracts 88 to 90 per cent of the zinc that is in his ore, and about 50 to 70 per cent of the lead."

The author concludes with a reference to certain misconceptions respecting the status of zinc smelting, as follows:

"The art of zinc smelting is far from being at a standstill. When we find 1000 kg. of ore requiring 1000 calories of heat being distilled with 1100 kg. of coal equivalent to 8000 calories, as is done in the best practice, we are observing a thermal efficiency of 12½ per cent, which compares favorably with good steam practice. When we find a ton of ore being smelted with 2½ man-days of labor, and consider that we are dealing with a concentrated product, and reflect that the total weight of material handled is relatively small and that the work on it from step to step is often more cheaply done by a man than by a machine, we do not feel unduly mortified by our results. Nor does the extraction of only 85 or 90 per cent of the zinc content of the ore shame us very much when we reflect upon the peculiar and troublesome metallurgical properties of zinc.

"Electric zinc smelting, which has engaged a good deal of attention during the last fifteen years, is metallurgically of the same nature as ordinary smelting; the main difference is that, in one case, the zinc is distilled by the heat of the elecric arc or the heat of electric resistance; while, in the other case, it is done by the combustion of coal. So far, electric smelting has become an art only in Sweden and Norway, where several thousands of tons of spelter are annually produced by this method. The smelters in Sweden and Norway enjoy very cheap power, whereby they have been able to overcome, or at least meet, the main obstacle that has heretofore prevented electric smelting from becoming a commercial art elsewhere."

Development of Zinc Smelting in the United States.—In this paper GEORGE C. STONE directs attention to the tremendous increase in spelter production during the last thirty years, and the fact that more than half of it has been the output of the United States. The first spelter produced in this country was made by the government in 1838 from ore from Franklin Furnace, N. J., and was used for making brass for standard weights and measures. The first serious attempt to make spelter in America was by Joseph Wharton, in Bethlehem, using oxidized ores from Friedensville. In 1856 or 1857 he employed Matthiessen and Hegeler to build a furnace. This was tried and abandoned. In 1859 Colonel Wetherill, of zinc oxide fame, built a spelter furnace that was not successful. Finally, in 1859, according to some reports, and in 1862, according to others, Wharton brought to this country Louis de Gée, an engineer from Liege, who built and operated a plant that, with some interruptions, continued to make spelter until 1911. In the meantime Matthiessen and Hegeler had built a works at La Salle, Ill., in 1858, and were operating successfully when the Civil War broke out. The plant was closed for a time, but opened again when the demand for spelter arose in 1862-3. The credit, therefore, for having first produced spelter on a commercial scale in this country belongs to Matthiessen and Hegeler.

The author traces the development of zinc smelting in different parts of the country, briefly describing the plants and their products. Matthiessen and Hegeler patented their spelter furnace in 1879, and it has been widely used since that time. In 1884 Hegeler patented his roasting furnace which is now used with modifications by every smelter in the country that makes acid. In addition to these important inventions, these metallurgists made many minor improvements in zinc smelting which have since been generally adopted.

The first zinc rolling mill was built by Matthiessen and Hegeler at La Salle in 1868, and has remained in operation ever since.

An entirely new process for making zinc oxide from ore was patented in the early '50s, and three patents were taken out in 1855 by Jones, Burrows and Wetherill, on almost identical lines. Burrows was employed at the Passaic Chemical Works. He states that "one night the flue from one of the furnaces that he was attending leaked, and he covered the hole with a piece of grate bar, throwing a shovelful of refuse on it. The refuse proved to be a mixture of coal and zinc ore, and the heat of the flue being sufficient to light it, Burrows soon noticed a cloud of zinc oxide coming off. He built a small furnace and repeated the experiment, and when he found that it worked again, showed it to the officers

of the New Jersey Zinc Company, among whom were Wetherill and Jones. The grate bars used were what are now usually called 'Wetherill grates,' but were in common use for boiler firing at that time in the vicinity of Newark, where they were made by Renton, who had a machine shop and foundry. Colonel Wetherill frequently stated that he had nothing to do with the invention of these grates, but his name has been persistently attached to them.

Colonel Wetherill proposed to Burrows that they work up an invention together, as Burrows had not the money to do so alone, but the proposition was declined, and each went ahead on his own account. The result was that three people applied for and obtained patents for substantially the same thing in the same year. Wetherill also took out patents for improvements in 1855-6-7-9 and two in 1868. The New Jersey Zinc Company acquired the patents of Jones and Burrows, but could not agree on terms with Wetherill. The latter shortly afterward sold a license to use his process to the Passaic Zinc Company. Both the New Jersey and the Passaic companies put the process in operation, as it proved to be a great improvement on those previously used. Everything went quietly until the Wetherill patent had nearly expired, when he brought suit against the New Jersey Zinc Company for infringement and accumulated profits. The suit that followed was long and hotly fought on both sides. The final decision of the court was that the furnace was Burrows' invention and the process Wetherill's and that half the profits were due to each. As the Zinc Company owned the Burrows' patent, it was obliged to pay half the increased profit due to the use of the invention, to Wetherill. The decision seems a very fair one, as while the original idea appears to have been Burrows', he had not sufficient knowledge or skill to develop it and make a working process of it."

The method of collecting oxide in bags was invented by S. T. Jones of New York in 1852 and is now universally used, not only for zinc oxide but other smelter products.

On the development of magnetic separation, the author says:

"About 1890, Messrs. J. P. Wetherill and G. G. Convers of the Lehigh Zinc & Iron Company, again attempted the separation, and this time with complete success. Their first method was to heat the ore to a very moderate temperature and separate on Wenstrom machines. This was patented by Mr. Convers, Dec. 20, 1892. They were not entirely satisfied with this method and continued their experiments, which resulted in the discovery, by Mr. Wetherill, of a new principle in magnetic separation—that of producing a highly concentrated field by using pointed pole pieces. Mr. Wetherill took out three patents on March 3, 1896, for the general principle, for the application of it to ores containing franklinite, and for the machine. A mill was built, and the willemite separated was used for the manufacture of spelter, and the franklinite for oxide, with a considerable increase in profits. Experiments were continued, and Sept. 28, 1897, Mr. L. G. Rowand patented an improvement in the machines, and March 7, 1905, another, which greatly increased the efficiency and has entirely displaced the earlier types in this country. In the earlier machines, both poles of the magnet were on the same side of the feed belt, with the result that less than half of the field was operative and the strongest part of it did no work. In Mr. Rowand's improvement, one pole is placed above the belt and one below; the former is pointed, the latter blunt. The entire field is thus available and the maximum possible lifting effect is utilized."

In 1901 the Blake-Morscher electrostatic process was patented. This and later patents were acquired by the American Zinc, Lead & Smelting Co., who also bought certain patents of P. H. Wynne and Millard Woodsome, both of which had been assigned to Charles H. Huff. These are the basis of the Huff process which is now used on suitable ores.

The successful application of flotation at Butte & Superior is the latest development in concentration of zinc ores.

Among new processes for treating zinc ores, the author notes hydrometallurgical methods using acids, chlorine and ammonia. None of these has come into commercial use, but a vast amount of experimenting has been done. Some work also has been done on electrolytic precipitation but without success, and the author is of the opinion that it is doubtful whether the method will ever be a commercial success. Electrothermic smelting also has received attention, notably by Woolsey McA. Johnson, who has made greater progress than any one else. The drawbacks to success are high power costs and difficulties in condensation. For ores containing metals other than zinc, the electric furnace may prove advantageous, but is not likely to become a competitor of coal or gas smelting purely for the production of spelter. The paper is concluded with tables and diagrams showing the production of spelter in the United States and the world.

In the discussion which followed, G. H. Clevenger thought that the author underestimated the importance of hydrometallurgy and electrolytic zinc refining. This is bound to become important at some places and interesting experiments are under way at Bully Hill, Palo Alto, Anaconda, Murray, Utah, and Trail, B. C. E. B. Braden said electrolytic zinc received at Selby was 99.7 per cent pure. L. H. Duschak emphasized that the power cost was not the controlling factor in electrolytic zinc production. S. E. Bretherton gave the cost as 1 cent per lb. with power at $36 per horsepower-year and as one-half cent at $17 per horsepower-year.

Lead

The Smelting and Refining of Lead.—A review of the present status of lead smelting in the United States, by Dr. H. O. Hofman of Massachusetts Institute of Technology, begins with the introduction of blast-roasting, which has revolutionized the details of practice. The use of this process has greatly increased blast-furnace capacity, and has modified the design of blast furnaces. Blast pressure has been reduced, and slags of higher silica content are produced. Coke consumption has been diminished. The following table gives a comparison of the work of the Huntington-Heberlein and the Dwight-Lloyd methods of blast-roasting at two different plants.

Item	At Murray	At East Helena
	Advantage Lies in Favor of	
Cost of installation	D. & L.	D. & L.
Cost of roasting	H. & H.	Even
Adaptability to charge	D. & L.	D. & L.
Metal loss	Even	Even
Physical condition of product	H. & H.	D. & L.

Lead bullion is desilverized by the Parkes process, excepting at Grasselli, Ind., and Trail, B. C., where the Betts electrolytic process is used.

"An important innovation with the Parkes process is supplementary treatment at Omaha, Neb., and East Chicago, Ind., of the refined lead by the Pattinson process in order to obtain from bismuth-bearing lead

bullion, as market product, corroding lead with less than 0.05 per cent bismuth. At Omaha metallic bismuth is produced; the bismuth content of lead bullion treated at East Chicago is not sufficiently high to warrant going so far.

"The treatment of blast-furnace matte has undergone some radical changes. Formerly this intermediary product was thoroughly roasted in different kinds of reverberatory furnaces, and added to the blast-furnace charges until its copper content had been enriched to about 14 per cent. The smelting of this pulverulent roasted product caused much trouble, as it separated from the siliceous part of the charge and disturbed the work of the furnace. All this has been obviated by rough-roasting the matte and then blast-roasting it either with siliceous ores or with the other ores that are to be used for making up the blast-furnace charge. The further treatment of 14 per cent copper matte is now carried on in basic converters. The older method, worked out at Maurer, N. J., is to treat lead-copper-iron matte in the same manner as copper-iron matte; i. e., with the additions of siliceous ores. A charge of matte and ore is blown until the ore has been scorified, the slag is poured off, and a second charge of matte followed by ore is given and blown; the operations are continued until the copper in the matte has been brought forward to furnish white metal, which is now blown to blister copper. A departure from the standard method of treatment has been made at the smeltery of the International Smelting Co., Tooele, Utah. Here the lead-copper-iron matte is blown without the addition of siliceous ore until practically all the lead and zinc have been volatilized to be collected in a baghouse. During the blow the iron is oxidized and a large part of the copper; the mixture is transferred to a basic copper-iron matte-converter working in the usual way with siliceous ore, the oxidized iron is scorified and the oxidized copper sulphurized. The result is that the lead blast-furnace has to treat only the lead fume of the baghouse instead of a large amount of lead-iron slag. The results of the modification have been most satisfactory.

"Very little speiss is produced in blast furnaces treating ores; some refineries, especially if they are unfortunate enough, at least from a metallurgical point of view, to have to treat arsenical silver ore from Cobalt, Ont., can not help but make speiss. There is no well established method of treating the unwelcome intermediary product. Blast-roasting has been successful in an experimental way; converting alone in a basic vessel has been a failure; converting with copper iron matte a success.

"The amount of flue dust formed in blast-furnace work has been greatly reduced. In spite of this, competition and the complaints of agricultural and other interests surrounding smelteries have forced these to make every endeavor to prevent fume and dust from passing off into the open. Thus most lead plants of any size are provided with baghouses, even when the pecuniary return they furnish is smaller than the outgo for cost, maintenance and operation. Much attention has been given to the filtration of fumes and dust. It has called attention to the important relation existing between the assay values of filtered fume and dust and the lead-silver content of matte and slag. In earlier times low values in matte and slag formed the criterion of good work; the baghouse has shown that very low assays of matte and slag are usually accompanied by high values of fume and dust; over-reduction caused volatilization. At present a balance is kept between the two.

"The Cottrell system of electric precipitation of fume has been installed at Garfield, Utah, for the collection of lead-bearing fume of copper-iron matte converters after it had been carefully tested on a working scale with a single unit. Experiments with blast roaster and blast-furnace gases have given results which show a satisfactory clearance of the gases from finely divided materials. At Trail, B. C., electric condensation is in operation."

In the discussion of this paper, E. B. Braden mentioned the tendency toward furnace shafts 19 ft. high and referred to a reduction by 50 per cent of the quantity of flue dust, due to sintering, at Selby.

Ore Dressing

Prof. Robert H. Richards' paper on ore dressing was an interesting historical sketch of the advancement of the art from primitive methods to modern times, reviewing the development of tables and jigs, pneumatic, electromagnetic, and electrostatic separation, and finally flotation.

Fuels in Metallurgy

The symposium on the utilization of fuels in metallurgy had been arranged and edited by Prof. C. H. Fulton.

Burning pulverized coal in reverberatory furnaces was discussed in two papers. In the first, by D. H. Browne, the author gives certain data regarding the work at the Canadian Copper Co. The first furnace equipped for coal-dust firing was 112 ft. long by 19 ft. wide, with an extreme inside height of 6 ft. The bottom was an inverted arch of magnesite brick.

The coal was ground to 200-mesh and blown into the furnaces through five nozzles, into which it was conveyed by screws. Early operations showed that furnaces designed along the lines of grate-fired reverberatories were not adapted to the new practice. The roof required frequent repairs on account of the excessive heat. The magnesite bottom was replaced with silica, and the roof was raised to give a combustion space 6 ft. 3 in. high above the skimming line. The manner of charging was changed, the ore being introduced along the sides of the furnace. These changes resulted in increased ratio of charge to fuel. Thus during the first three months of 1914 the monthly average of tons of charge smelted per ton of fuel was 5.0, 5.65 and 6.77.

In the paper by E. P. Mathewson, Anaconda practice is briefly described. Two points are essential for the success of coal-dust firing: the coal must be dry, containing less than 1 per cent moisture before pulverization, and the grinding must be carried to a very fine point. Preferably, 95 per cent should pass a 100-mesh screen, and 75 per cent through 200-mesh. The flame is as easy to handle as gas. About 50 per cent of the ash is absorbed by the charge and the balance caugh in the flue connection to the waste-heat boiler. With the use of coal-dust firing and side-wall charging, it is no longer necessary to stop the furnace for fettling, and in the larger furnaces the flow of slag can be continuous as in copper blast furnaces.

Gas producer development is discussed in a paper by Z. C. Kline. The author finds the gas producer growing in popularity as natural gas becomes scarcer and oil more expensive. Development has been toward mechanically operated producers and toward designs for gasifying bituminous coal and fixing the tarry constituents. Mechanically operated producers are more expensive to install, but labor cost is reduced, capacity increased and more uniform gas produced. The gas-producer industry suffered somewhat from installa-

tions that did not come up to expectations, but the earlier difficulties have been simplified, and many plants are now working satisfactorily.

The trend of gas producer operation will probably be toward the perfection of mechanical types and more experiments toward simplifying and cheapening the methods of obtaining clean producer gas, and, no doubt, a great deal more attention will be paid to the operation of the producers already installed, especially along lines of labor and technical efficiencies. A great many firms now have appliances for checking up quality of gas, amount of coal used, and temperature control. At last, manufacturers are realizing that a gas producer cannot be run efficiently without competent men.

Surface combustion is reviewed in a paper by Prof. C. E. Lucke, the inventor and original patentee of the process. When air is perfectly mixed with gaseous fuel, in chemically combining proportions, the products of combustion are free from both fuel and oxygen. The mixture burns at the maximum possible rate because of the absence of flame volume and regardless of the nature of the surrounding atmosphere. For the commercial applicability of the combustion of such explosive mixtures, a definite localization of combustion zones is necessary, and means must be provided to prevent "back flash" and "blow off" due, respectively, to inferior and excessive flow velocity as compared with that of flame propagation. Back heating from the combustion zone along the walls of the feed passages to the mixture supply point, must also be prevented, either through thermal resistance or cooling by circulation of air around the passages. Perfect cooling prevents "back flash" regardless of flow velocity; with imperfect cooling it is prevented by a drop in pressure through supply exits varying from 0.1 in. water column to larger values, according to the size of the passages and burning rates of the mixtures.

"Excess exit velocity from the passages, which is normally necessary to prevent back flash, must be promptly reduced to prevent blow off, by spreading the mixture stream just beyond exit from the passages by baffles of solid refractory surfaces or by porous beds such as layers of granular refractory material, loose or bonded. These refractory spreaders become incandescent, permanent fire beds, converting a maximum of the heat generated into the radiant form, and they incidentally act also as accelerators of the combustion reaction.

"Accordingly the combustion zone may, it has been found, be definitely and permanently localized by utilizing the properties of the explosive mixtures themselves, and as a result there is now available for commercial application a new method or system of gas combustion, characterized by maximum possible rate of combustion, by maximum possible temperature of gases, because of minimum weight of products per pound of fuel, and by products containing normally no free oxygen and no unburned fuel, though by adjustment of proportions the products may be made either oxidizing or reducing."

Experiments on Sewer Pipe and Drain is the subject of Bulletin No. 7 of the Utah Engineering Experiment Station, Salt Lake City. The author is Prof. E. H. Beckstrand. Pipes were tested under all sorts of stresses, internal and external, and very complete information is given.

The **Brown Instrument Company**, Philadelphia, Pa., has just let a contract for an addition which will furnish nearly 50 per cent additional floor space. The factory, which a year ago seemed sufficiently large, has been outgrown, due to the large demand for Brown pyrometers for high-temperature control.

Opportunities for the American Chemical Industry*

BY EDWARD EWING PRATT

Chief Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D. C.

The Department of Commerce is deeply interested in the chemical industry and aims to facilitate its development in every way. The department realizes that no other branch of American industrial activity has been forced to deal so swiftly and effectively with a great variety of extremely difficult problems. The chemical industry of the United States along with other industries found a very serious situation at the outbreak of the European war, and the last year has been a period of readjustment and reorganization.

The National Exposition of American Chemical Industries is significant because it illustrates the fact that American chemists and American chemical manufacturers have, through their own inventive skill, their own talent for organization, and their own thorough knowledge, been able to accomplish a great deal during the last twelve months. It can be fairly said that at the present time the American chemical industry is well established and that American firms need no longer be dependent for chemicals upon any foreign country. This is a tremendous accomplishment and it is extremely significant in the development of American industries.

The effects of the great European war have been noteworthy in our American industrial life. On the whole, they have been of a twofold nature; there are direct, visible results, essentially of a transitory nature and destined to disappear with the approach of peace. There are other results less evident to the eye but increasing with every added day of the conflict and bound to be of far-reaching import in the development of our industries.

Among the more important temporary effects of the war are those which have to do with the furnishing of supplies for the various belligerent activities in Europe. We are furnishing not only large quantities of foodstuffs and live stock, but considerable quantities of shoes, wearing apparel, saddlery, motor trucks, railway supplies, iron and steel in all kinds of shapes and forms; lead, zinc and copper; fire-arms and ammunition. For the time being these specialties are stimulating considerable activity in our industrial plants. Whether it is an altogether healthy activity, and whether it will not lead to serious economic consequences is a question. In so far as our manufacturers count on this activity as definite increases in their business and as a permanent increase in production, so far will they be unprepared for the cutting off of this activity at the end of the period of hostilities.

A review of the chief industries ministering particularly to the temporary needs of the belligerents across the Atlantic shows clearly the final outcome will be a very material addition. Part of this plant will be simply anticipatory of the normal growth of the company's mechanical equipment. Part must lie idle in time of peace, but is a distinct asset in the national preparedness for an adequate defense against attack. The remainder furnishes at once products needed in the healthful expansion of our industries, and particularly of the chemical industry.

Less conspicuous and spectacular, but of far greater permanent value, is the impulse given to the manufacture on American soil with American raw materials of a variety of articles for which we have heretofore been dependent upon foreign skill and enterprise. In a more

---

* An address made before the First National Exposition of Chemical Industries at New York City on Sept. 25, 1915, slightly abstracted.

or less uncomfortable way we have suddenly been brought to recognize the folly of shipping vast amounts of crude material of our farms, forests and mines 3000 miles across the ocean and buying it back in a manufactured form at a vastly enhanced price. We have likewise come to recognize the absurdity of allowing many natural products of the tropics, of South America, of the Far East, to find their way to Europe and of paying foreign intelligence and skill to transform them into articles of daily need in our lives.

The complete cessation of imports from Germany and Austria and the serious restriction in our purchases from many other countries have taught us these two lessons. It is in the practical application of these lessons that the American people will derive their fullest benefit from this otherwise so deplorable world conflict. American skill, ingenuity, adaptability, inventive talent, scientific attainment and general enterprise have promptly rallied to meet widespread demands to establish on our own soil the permanent manufacture of a number of wares, some of minor, others of major importance. The return of peace will see them well rooted and able to withstand foreign competition.

There are a number of industries which might be cited where we have heretofore been dependent upon Europe and have since the outbreak of the war begun to manufacture for ourselves—the curved faces of our clocks and watches, fine brushes for water-color use, chloride and carbonate from domestic barium minerals, chemical porcelain and optical glass are cases in point.

Prior to the war we imported from Europe, chiefly from Germany, coal-tar dyes valued annually at nearly $10,000,000. Our vast textile interests, the great industries producing paper, ink, varnish, pigments, etc., were dependent upon these importations for the element of color in their wares. To every tailor, to every milliner, in fact, to every consumer of colored articles, it has been a matter of vital necessity that there should be no interruption of the regular arrival of the hundreds of varying hues produced upon the banks of the Rhine from prosaic coal tar.

There was a limited production of these artificial dyestuffs in the United States. Unfortunately the domestic production has been dependent hitherto upon Europe, and again chiefly Germany, for its raw materials, the semi-manufactured so-called intermediates, such as aniline, salicylic acid, etc.

The supplies of intermediates ceased with the outbreak of the war. The importations of finished dyes from Germany were intermittent and finally stopped altogether in March of the present year. Conditions threatened to paralyze the activities of our textile interests and of allied industries. There has been a certain amount of displacement in the mechanism of production, unavoidable under the circumstances, as the available stores of artificial dyes steadily disappeared from the storerooms of textile and other mills.

Thus far the disaster has been less serious than we feared it might be four months ago. Forced to make material changes in designs and in processes with more or less incidental losses, there is little doubt but that the sum total of the losses borne by American industries during the year 1915 in consequence of the cessation of the importations of foreign coal-tar dyes will far exceed the amount of capital needed to establish upon our own soil a complete self-contained American coal-tar dyestuff industry, using exclusively American crude materials and meeting adequately all the nation's needs for artificial colors.

In this connection the users of dyestuffs in this country should have the co-operation of every consumer. Up to the present time manufacturers have been using the stores of dyes which were left on hand or which have been meagerly supplied since the opening of the great war in Europe. Before our own industry can produce the necessary amount of dyestuffs there will be a certain hiatus during which it will be impossible to get the same kind of colors and the same qualities and shades of colors as has been possible heretofore. Garment wearers—men. women and children—will have to be content with plainer and more prosaic standard colors. Consumers will have to forego the use of the more intense and delicate colors which were obtainable from the various coal-tar products. This applies not only to outer garments, but to shirts, women's waists, neckties, hosiery and underwear. In fact, to everything in which dyes are used for the production of fine colors in the daily wear of people.

It therefore behooves the people of this country to be considerate, and if only plain colors are obtainable, or if colors are used which do not stand the test of exposure to weather and climate, not to blame the manufacturer of the garment or the manufacturer of the colors.

American industry, however, has taken hold of this problem in a particularly rapid and satisfactory manner. Each week witnesses the addition of new firms engaged in solving the problem of a domestic supply of coal-tar colors either by furnishing crudes or intermediates for finished dyes. Increasingly large amounts of capital are being devoted to this new industry, and there is an intelligent awakening of both capital and enterprise to the opportunity offered for establishing a fairly complete coal-tar chemical industry on American soil.

One of the especially interesting features of this exposition is that of a pioneer company in Buffalo, which has been able to prove that the United States can create a complete comprehensive and self-contained coal-tar chemical industry, fully capable of meeting the demands of the great textile industry and the scores of allied interests in which these colors are of vital importance. In fact, American chemists have concentrated their efforts upon the solution of the dyestuff problem, and, noting the creative ability which is being applied to these problems, I am sure that a solution will be reached.

The United States has also been dependent upon Europe for its supplies of potash. These supplies have been used exclusively for fertilizers which are especially needed in the cotton plantations of the South and are indispensable to the crystal products of our glass works. The United States has been content to receive its supplies from Europe. These supplies were suddenly cut off. Under these conditions the American manufacturer has turned to the resources of his own country and has been able to arrive at a practical solution of this very difficult question, for a method has been discovered by which the tons of kelp on our Pacific coast can be utilized as a means for securing potash supplies. It is therefore with peculiar satisfaction that I have learned from the official of the Bureau of Foreign and Domestic Commerce who has been in charge of the investigation in this field that several processes of real economic promise have been discovered, and there is no doubt that the securing of potash from the kelp fields of the Pacific will soon be established upon a broad industrial basis.

It would be scarcely in accord with the usual development of industry to recommend that we should slavishly imitate the example of any foreign country. It is worth while, however, to consider the methods and success of Germany in developing her chemical industry. In 1860 the chemical industry of the world was developed to its highest extent in England, with France a close second.

It was not until about 1875 that Germany began to show great activity in this industry. Her development, however, was as rapid as it was unforeseen, and in the face of serious obstacles. Even for many years after this date Germany had to rely upon imports for many of the principal staple materials required by the chemical industry, such as soda ash, bleach, coal tar, ammonia compounds, etc., from other countries, especially England. Even as late as 1879 Germany's imports of soda amounted to 24,000 tons, which constituted the entire consumption for that year. In 1910 the imports of soda had fallen to 154 tons, while the exports had amounted from zero to 62,500 tons, representing the excess of production over consumption.

Similar instances illustrating the growth of the German chemical industry can be quoted in any number. Not only did England and France have the start of Germany in the matter of raw materials, but those countries also to a considerable extent had a corner on the market for technical skill which was required in the development of the chemical industry. In spite of these handicaps, Germany went forward to such a point that before the opening of the European war she controlled many branches of the chemical industry and other countries of the world went to her for their supplies. This is particularly true of the coal-tar industry and the manufacture of synthetic dyes.

Chemistry has truly been called "The Intelligence Department of Industry," and it is therefore peculiarly important that we should develop a chemical industry in the United States. It is not merely a matter of a single industry or the matter of attaining increased efficiency or a wider variety of products in one industry, but applied chemistry is largely the successful utilization of by-products and, therefore, the development of a chemical industry in the United States means increased efficiency and increased economy in every industry in this country.

It is also pertinent to point out that perhaps the fundamental reason for the peculiar success of the German chemical industry has been the willingness to devote years and years of effort, of careful scientific experimentation to the development of a process or a new product. It is this long-time investment for the future, the idea of unceasing experimentation, that American industry must learn.

The progressive development of industry—this is particularly true of the chemical industry—parallels the development of science and knowledge. The nations whose natural products are the most intense and the best utilized are also those which attain industrial supremacy.

The United States should be independent of all foreign sources for all its chemicals, for the United States has within its own boundaries the raw materials for the production of such chemicals. This exposition tonight illustrates the fact that chemical manufacturers are alive to the possibilities of the present situation. It shows, too, that the national government is earnestly seeking to encourage and facilitate the growth of the nation's chemical industry. The Bureau of Foreign and Domestic Commerce, which has had such an active share in this exposition and through the work of its own commercial agent is attempting to solve some of the difficulties which have confronted some of our chemical industries, feels that the chemical manufacturers of the United States are opening up a new epoch in American industry, and that as a result of the transformation which is taking place the United States will not only be a producer of its own chemical needs, but that the United States will undoubtedly secure a large share in the chemical markets abroad.

Accident Prevention in the Chemical Industries*

BY FREDERIC W. KEOUGH
National Association of Manufacturers

A recent bulletin of the Bureau of Labor Statistics of the U. S. Department of Labor, presents an estimate that 25,000 fatal industrial accidents occur annually among American wage earners and approximately 700,000 accidents occur which involve a disability of more than four weeks' duration. The industries which contribute to the greatest number of fatal accidents are railroad and agricultural work, each causing about 4200 fatalities per year. Coal mining causes more than 2600; building and construction work only 1900, and general manufacturing about 1800.

In an effort to get some statistics on accidents and accident prevention in the chemical industries, I wrote to some sixty concerns and to my first letter received only three acknowledgements of any sort. A second letter to the same parties brought little more in the way of results. From this one might assume that chemical establishments are not interested in accident prevention. There is, however, excellent testimony from a few sources to the contrary. It may be concluded, nevertheless, that there are no particular hazards in the chemical industries, other than those of running machinery. Pains should therefore be taken to educate workmen when engaged on special jobs and proper remedies should be near at hand in case an accident should occur. For instance, as a special aid soda ash should be stored in convenient places in case of breakage of acid carboys or similar injuries to the men. A first-aid department should be installed to treat minor injuries, and if the size of the plant justifies, a physician should be on the house staff. For emergency use there is nothing better than the N. A. S. O. jar—N. A. S. O. meaning National Affiliated Safety Organizations, namely the National Founders Association, National Association of Manufacturers, National Metal Trades Association, and National Electric Light Association.

This jar was developed to meet all requirements of a compact, convenient, sanitary-first-aid outfit. It is structurally strong and its arrangement allows quick removal of any article without disturbing the rest. It includes every material which a large conference of physicians with an extensive experience in the treatment of injuries, agreed upon as necessary for effective first-aid treatment by laymen. The jar is especially useful as it can be transported readily from place to place. Some employers, in fact, place a jar on every truck or wagon used in connection with outside work. The jar, like the standardized safety goggles, foundry leggings and shoes, is sold at cost price as there is no intention to make a profit on the devices.

First aid, in order to result in the decrease of accidents and in the prevention of serious consequences following slight injuries, is dependent upon three factors, namely:

(1) Properly equipped and properly managed emergency rooms with competent first-aid man in charge in the smaller works; in the larger works, attendant physician and nurses are requisite.

(2) The intelligent and willing co-operation of every workman in the prevention of accidents. All workmen should familiarize themselves with, and put into practice, the company's rules requiring the immediate reporting to the emergency room of all injuries for treatment.

*An address delivered at the National Exposition of Chemical Industries at the Grand Central Palace, New York City, Sept. 22, 1915.

(3) The instructions of every man at the works to see that proper attention is given to his injuries in order to prevent their becoming serious. This may be accomplished by the organization of first-aid squads which, of course, should be properly instructed by the physician in charge in all the elements of emergency practice. One of these squads should be organized in each department, and it will be of decided advantage to arrange for a similar rotation of service as is operative in the work committees.

The timely treatment of injuries will always result in a rapid cure and consequently in a reduction of expenses.

Chemical companies, let us believe, are interested in accident prevention in a general way even though they have few recommendations of ways and means especially adaptable to their industry. It is a source of great satisfaction to learn that the safety department of *American Industries*, the magazine of the National Association of Manufacturers, has enjoyed the appreciation of the chemical industry. In the promotion of safety work we have issued a four-page supplement for the last three years, devoting each issue to some particular topic and showing in colored illustrations, innumerable devices that may be made in any shop.

As to causes of accidents in the group comprising manufacture of paints, oils, etc., an indication as to the principal sources is found in a bulletin of the New York State Department of Labor for 1912 and 1913, which shows in 2642 cases, 575 accidents caused by fall or weight of objects; 508 by miscellaneous accidents; 449 through heat or electricity; 341 by falls; 292 by working machinery; 168 by hand tools; 136 by conveying and hoisting machinery and 86 by power transmission.

The accidents directly related to the manufacture of chemicals are largely occupational diseases or burns from acids or poison by some mineral. Especially dangerous minerals are lead, arsenic, mercury and phosphorus. In addition we have the danger of acids which corrode the skin and act as caustic and in vaporous state attack teeth. Wood alcohol produces blindness if taken internally or even if breathed in large quantities; and gases such as carbon monoxide, methane or marsh gas are deadly. In fact, all of the hydrocarbons are more or less poisonous. One of the ever-present dangers is that if there is any corrosion of the skin or any skin disease which may arise from certain products, such as varnish, other diseases are engrafted on it. The principal thing is cleanliness of the hands, so wash basins are necessary and many times gloves. Some of the anilines are also poisonous. Dust is also a factor in the manufacture of some chemicals. There is danger in many lines of explosion, particularly now in the rapid manufacture of so much powder and high explosives. The principal lines of prevention are dust hoods, washing, etc.

The list of industrial poisons is a long one and since they attack from so many points, they must be studied closely. Here is the list that is entitled to special attention: Acetaldehyde ethylaldehyde, acridine, acrolein, ammonia, amylacetate, amylalcohol, aniline, aniline dyestuffs, antimony compounds, arsenic compounds, arseniureted hydrogen, benzine, benzol, carbon dioxide, carbon disulphide, carbon monoxide, chloride or lime, chlorine, chlorodinitro-benzol, chloronitrobenzol, chromium compounds, cyanogen compounds, diazomethane, dimethyl sulphate, dinitrobenzol or binitrobenzol, formaldehyde, hydrochloric acid, hydrofluoric acid, lead, manganese dioxide, mercury, methyl alcohol, methyl bromide nitraniline, nitrobenzol, nitroglycerin, nitronaphthalene, nitrous gases, oxalic acid, petroleum, phenol, phenylhydrazine, phosgene, phosphorus, phosphorus sesquisulphide, phosphureted hydrogen, picric acid, pyridine, sulphur chloride, sulphur dioxide, sulphureted hydrogen, sulphuric acid, tar, turpentine oil.

Since these attack through the respiratory organs, by absorption through the uninjured skin, through the digestive organs, specific measures for the protection of workers must be devised. The suggestions laid down by Dr. R. Fischer of Berlin, are comprehensive enough to repay study and application. These are:

1. Properly adapted buildings, thick walls of separation for dangerous rooms, good lighting, facilities for keeping the workshop clean and for effective ventilation.
2. Apparatus adapted to its special purpose, whenever possible, closing tight in every part.
3. Appliances for accomplishing the arrest of gases and dust at their place of origin, their removal (by exhaust fans) and in a suitable manner rendering them innocuous or collecting them, thus preventing them from entering the nose and mouth.
4. So far as possible, avoidance of direct contact with poisonous materials or substances injurious to health in working with, transporting, or packing them.
5. The displacement of particularly dangerous labor methods and materials by the introduction of less dangerous labor processes and materials, as well as by the employment of materials satisfactorily pure chemically.
6. Instruction of workmen just entering upon an occupation concerning the properties of the poisonous substances extracted, manufactured, used, or otherwise evolved, and, whenever possible, caution leaflets should be put into the hands of the workers.
7. The repetition of this instruction at frequent intervals.
8. Posting of precautionary regulations and warning placards containing admonitions for the exercise of special caution and enjoining the observance of measures for insuring safety. Constant supervision of all dangerous employments by expert and responsible persons.
9. Employment by appropriate means for personal protection as work clothes, caps, gloves, goggles, and, as necessary adjuncts, mouth and nose shields, respiratory masks and the like, in case the appliances named in rule 3 are inapplicable.
10. Practice of bodily cleanliness by the use of wash, bath and dressing rooms, the use of special rooms for eating, separate wardrobes for street and work clothes, and frequent, nonhazardous cleansing of the clothing.
11. Immediate report of symptoms of indisposition, attention to wounds of the skin caused by the handling of corrosive materials, the speediest employment of an unexceptionable antidote giving promise of success at the very first symptoms of poisoning, with the simultaneous summoning of a physician.
12. The installation of a healthy working force capable of withstanding exposure to the poison. Temporary or permanent exclusion of sick workmen from the dangerous departments of the industry. Medical examination of the workers in dangerous employments at suitable intervals. Under certain circumstances there should be a change of work in occupations giving rise to chronic poisoning.
13. The utmost possible reduction of the hours of labor in dangerous employments.

Satisfactory statistics are not available, showing the number of cases of poisoning resulting from the inhalation of poisonous fumes and vapors in the various industries of the United States. Physicians in this country have reported many cases that have come under their observation, insurance companies have had considerable similar experience, and other cases are brought to light through the reports on occupational diseases that are required by law in some of our States. These returns are incomplete, however, and they utterly fail to reveal the seriousness of the situation.

It is of the utmost importance that the men who are to work at dangerous occupations be carefully selected, because some persons, by reason of physical infirmities or deficiencies, are totally unable to withstand the unhealthful conditions that are sometimes associated, more or less unavoidably, with our manufacturing plants. Before engaging in hazardous work of this nature, each man should be carefully examined by a

competent physician, and similar examinations should be made thereafter, periodically and regularly. In plants making use of hazardous processes, there is no doubt that both the efficiency and the health of workmen are better when reasonably short hours are the rule, and when stated rest periods are allowed.

Heads of departments should co-operate with their men in having all thoroughly aware of the hazards of any special operations. They must impress on their workers that among them should be foremost the accident prevention spirit. They should realize as vividly as do the managers of the plant that accidents are bad business, aside from humanitarian and sentimental considerations. Accidents increase insurance premiums and it is only a common business principle that it is necessary to reduce expenses as far as possible in this and every other direction.

The accident insurance companies and the State factory inspectors are entitled to much credit for the reduction of accidents through their insistence that the requirements made by the inspector are complied with. Factory inspection and inspectors have grown into something like a burden in all lines of industry; in the direction of safety inspection can scarcely be too frequent or too searching.

In a chemical works there are machine shops in the buildings, woodworking and similar mechanical risks, that can be solved according to the best modern practice in safeguarding and safety appliances. All necessary precautions should be taken in chemical plants to install proper safeguards around machinery, elevators, boilers, railway tracks, etc.

Beyond these risks are those inherent in the processes of manufacture of the so-called heavy chemicals, sulphuric, nitric, muriatic, hydrofluoric acids and their by-products, sulphate of alumina and other alkaline products. There is a certain negligible risk from fumes in the operation in the manufacture of acids, but this is very remote, the most dangerous fumes being those produced in the manufacture of nitric acid, which are released only through the breaking down of some portion of the apparatus. The most dangerous of the acid burns are hydrofluoric, nitric and sulphuric. The burns caused by these acids getting on the skin are very severe and painful.

To protect the eyes of men working with these acids in any situation in which there is danger of splash should be obliged to wear rubber-lined goggles, fitting close to the face. All bad results from getting the acid on the person can be avoided entirely by thorough washing with plain water which dilutes and removes the chemical from the skin.

The General Chemical Company, which has an admirable safety organization, furnishes men working on acid pipe lines with a rubberized cloth hood with mica covered eye openings to be worn whenever they are loosening or tightening valves or separating flanges, to guard against a sudden squirt of acid which might strike them in the face and eyes. In working in the alkaline processes, the men wear rubber gloves furnished them.

Cooling pans containing hot liquids are railed off to a height of 3 ft. to prevent men from stumbling and falling into them. In dusty processes, as in other industries, men are obliged to wear respirators of some approved type.

In the heavy chemical industry the matter of ventilation of process buildings is simple, since in general they are large and high with ample openings near the roof for the escape of any gases or fumes. The chief means adopted by the General Chemical Company to prevent the industrial accidents inherent in the manufacture of chemicals is the careful education and supervision of the men.

An effective device for use in filling laboratory stock bottles for strong acids from carboys is forcing the acid, or the ammonia, from the carboy through a glass tube by means of compressed air. The air is freed from impurities by passing it down through a 5-ft. iron pipe filled with fairly fine coke. An attendant must always be present with the regular operator during the filling of these bottles.

Systematic schemes for preventing accidents are not new in the United States. Some large employers have had efficient systems for a number of years, but efforts were not sufficiently widespread and, as a national movement, accident prevention was in the United States up to a few years ago far behind other industrial nations. American statesmen, employers, economists, insurance experts and humanitarians of all classes have called attention to the need of greater and more concerted action and much has been done in the last three years.

The present time finds the people of our country far more active in accident prevention than any past period. This activity will continue and increase for years to come and those who have had the opportunity to investigate this subject here and in European countries believe that we are gaining headway and that within a few years will overtake some of the nations who have preceded us in the movement from fifteen to twenty-five years.

In the face of all the safety work that is being done by societies, by associations, by manufacturing plants, by individuals and the press, it is strange that one finds Secretary Frank Morrison of the American Federation of Labor, in a speech last Labor Day, uttering for obvious effect this grave misrepresentation: "Let us not forget that 30,000 of our fellow-countrymen engaged in gainful occupations are killed every year. Men talk about preparedness, but never a word of protest at the annual loss of these thirty regiments that are silently swept into unknown graves *that dividends may continue.*"

An investigation made of a large number of concerns that have reduced their accident records an appreciable per cent, proves conclusively that mechanical safeguards only prevent from 25 to 40 per cent, while the remaining 75 per cent can be prevented only by education, inspection and co-operation of the workmen. Even in the smallest plants, it is necessary to have some form of a safety organization in order to keep employees interested and on the look-out not only to safeguard themselves from injury, but their fellow workmen as well. One of the greatest means of getting the desired co-operation is that of allowing men to serve on committees and give them some responsibility in the work. Where this plan has been followed, 95 per cent of the suggestions for safeguarding submitted, have been found practical and were adopted.

The central committee should have as a member at least one of the executive heads of the concern, not only to give it prestige but authority as well. It should serve as a general clearing house for all safety matters and devise ways and means for keeping safety interest aroused and obtaining the co-operation of employees. Regular meetings should be held, preferably monthly, at which time all serious accidents should be discussed and measures taken to prevent their future occurrence. Proceedings of the shop committee should be considered and action taken on recommendations offered, and guards ordered installed that are deemed necessary. The report of periodical inspection made by the safety man should be considered and investigations made of dangerous conditions reported.

The shop committee should meet at least monthly and all dangerous conditions discussed and suggestions made to remedy them. The personnel of the committee should be changed at least every three months so that as many as possible can be drawn into intimate touch with the work and the interest aroused. Since workmen make the best inspectors, they should be encouraged to report conditions in their departments that they usually see in the course of their regular duties, as with plants of the size here discussed, it is hardly necessary to devote a definite period of time to inspection work.

Even in plants of the smallest size, some one person should be detailed to see that safeguards are constructed in accordance with various standards adopted and report to the central committee, when the work has been completed on the progress that is being made. Such a man can usually be found in the drafting or mechanical departments and should be required to make periodical inspections of the entire plant and report on conditions found.

One of the greatest factors is keeping employees interested in a regular "booster" or get-together meeting. A "smoker" often serves the purpose, at which time stereopticon or motion pictures relating to safety can be shown and by the aid of talks by various members of the firm or an authority on accident prevention, the subject can be impressed on their minds and their co-operation obtained. At these meetings the cause and prevention of accidents should be freely and frankly discussed which will tend to bring a closer relationship between employer and employee, which will not only aid in accident prevention, but will aid in disseminating any industrial discord that may have a tendency to arise. The solution of the whole accident problem is to get the men with you, then do your part, and accidents will take care of themselves.

It is conceded generally, says a well-known safety engineer, that the older employees resent the safety idea more than the younger men, and it is only natural that this be true. After a man has operated a machine for a number of years without sustaining an injury, he naturally would feel as though it was a reflection on his ability to have safeguards applied. This condition is particularly found in small shops, and it requires some tact in approaching the employees and gaining the desired confidence. After such an employee is once won over to the side of safety, he will usually prove a very ardent "booster" not only in preventing accidents, but in pointing out dangerous conditions.

First National Exposition of Chemical Industries

To supplement our report of the exhibits given in our issue of Oct. 1, we herewith give an account of a few exhibits which were omitted through error of the printer in our last issue.

Condensite Company, Bloomfield, N. J.—Exhibit of the various products made from "condensite," among which were the Edison records, switch board meters, the Remy ignition generator, golf clubs, automobile steering wheels and numerous other articles of all kinds. Their exhibit also included Hallowax, which is made from chlorine and napthalene and used for fire extinguishers and in places where a high specific inductive capacity is required. Mr. Sanford Brown was in charge.

L. O. Koven & Brother, Jersey City, N. J.—Showed small models of water still and benzol still, and also a large size Kelly filter press manufactured by them. Dr. Emil E. Lungwitz was in charge.

Standard Aniline Products, Inc., New York City.—Showed samples of nitraniline, beta naphtol, permanent red, sulphur black and para-nitraniline.

Werner & Pfleiderer Company, Saginaw, Mich.—Exhibited four small models of their kneading and mixing machines and one large "Universal" mixing machine was shown with the top removed so that inside mechanism could be seen. Mr. F. H. Banbury was in charge.

The following list comprises the names of those who registered either at the booth of the American Electrochemical Society or at the booth of METALLURGICAL AND CHEMICAL ENGINEERING. Where no address is given New York City is understood:

Paul O. Abbé; Wm. H. Abeling; Aberman & Son; Jerome Alexander; B. Alperowitz; M. E. Alpers, Dover, N. J.; L. T. Alton; H. S. Amer, Bloomfield, N. J.; American Alkali & Acid Company, Bradford, Pa.; Wm. C. Andrews, Orange, N. J.; D. W. Armstrong; Louis V. Aronson, Newark, N. J.; D. Irving Ashworth, Wappinger Falls, N. Y.; L. H. Baekeland, Yonkers, N. Y.; Robt. J. Ball, Newark, N. J.; Will H. Baltzell, Pittsburgh, Pa.; John H. Banks; E. J. Bartlett, Hanover, N. H.; Chas. Baskerville; J. W. Beck, Rosiclare, Ill.; A. E. Bellis, Chicopee Falls, Mass.; R. C. Bergen; H. S. Blackmore, Washington, D. C.; D. M. Bliss, Kingsland, N. J.; J. E. Bloom, Brooklyn, N. Y.; E. Blough, Pittsburgh, Pa.; P. L. Blumenthal, Lexington, Ky.; Walker Bowman; W. H. Baynton, Grasseli, N. J.; Chas. S. Bradley, Linn Bradley; Walter M. Bradley, New Haven, Conn.; William Brady, Chicago, Ill.; H. B. Branerr, Seattle, Wash.; E. J. Bremnesen, Elmhurst, L. I.; T. Lynton Briggs, Flushing, N. Y.; W. H. Broadhurst, Brooklyn, N. Y.; H. E. Brown, Kingston, N. Y.; C. L. Bryden, Scranton, Pa.; Lucien Buck, Rochester, N. Y.; Robt. H. Buckie, Mechanicville, N. Y.; R. Buisemeister; W. G. Bullard, Dover, N. H.; D. G. Bunicke, Philadelphia, Pa.; C. F. Burgess, Madison, Wis.; J. W. A. Butler, Brooklyn, N. Y.; Alison Butts, Chrome, N. J.; J. R. Cain, Washington, D. C.; Harry S. Calvert, Pittsburgh, Pa.; R. P. Calvert, Henry Clay, Del.; Arthur J. Campbell, Bridgeton, N. J.; Frank W. Cann, Newark, N. J.; Jessie Y. Cann, Urbana, Ill.; H. Carmichael, Boston, Mass.; H. M. Carter, Norwood, Mass.; George S. Cary; C. F. Chandler; P. L. Charter, Bridgeport, Conn.; J. B. Churchill, State College, Pa.; G. W. Clarke, Cleveland, Ohio; E. A. Colby, Newark, N. J.; Albert A. Cory; Alfred H. Cowles, Sewaren, N. J.; J. R. Crocker; W. L. Cummings, Philadelphia, Pa.; F. W. Cunningham, Orange, N. J.; Thos. Darlington; Ralph W. Deacon, Chrome, N. J.; C. F. De Ganoke; J. R. de la Torre Bueno, White Plains, N. Y.; Demaras Bros., Athens, Greece; C. H. Demproolf, York, Pa.; H. C. Diercks, Ithaca, N. Y.; Carl Dittmar; Wm. Donald, Ridgefield Park, N. J.; Chas. A. Doremus; L. B. Drekerson; Gustav Drobegg, Brooklyn, N. Y.; J. W. Drummond; Wm. R. Duggan; E. N. Dukern, Monte Carlo; Arthur J. Dwight; Thos. A. Edison, Orange, N. J.; L. A. Ehnhardt; August Eimer; Carleton Ellis, Montclair, N. J.; N. H. Emmons, 2d, Englewood, N. J.; Henry C. Enders; H. W. Engle, Marietta, Pa.; H. W. Faint, New Brunswick N. J.; E. W. T. Faint, Roselle Park, N. J.; J. Wm. Fehnel, Bethlehem, Pa.; P. B. Fehl, Reading, Pa.; Colin G. Fink, East Orange, N. J.; Staats L. Fink, Newark, N. J.; Chas. B. Foley, Ann Arbor, Mich.; W. A. Forbes; Albert Ford, Bridgeport, Conn.; Chauncey E. Foster; C. Fuld Frank; M. M. Franklin, East Orange, N. J.; H. A. Frasch; F. W. Frerichs, Jr., St. Louis, Mo.; R. C. Gardner, York, Pa.; David S. Giles, McKeesport, Pa.; J. S. Goldbaum, Philadelphia, Pa.; H. A. Goldman; S. M. Goldsmith; W. E. Gray, Elyria, Ohio;

TWO MORE EXHIBITS FROM FIRST NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES

F. W. Green, Little Falls, N. J.; Martin L. Griffin, Rumford, Me.; Elmer S. Grymes, New Brunswick, N. J.; C. A. Hall, Philadelphia, Pa.; W. T. Hall, Jr.; J. C. Halpenny; Fred J. Hambly, Buckingham, Que.; Wm. J. Hammer; Wm. H. Hampton; James O. Handy, Pittsburgh; J. W. Hansen, Troy, N. Y.; C. A. Hanson, Schenectady, N. Y.; C. K. Harding, Chicago; R. F. Harrington, Boston; Edward Hart, Easton, Pa.; Frank Hartwick, West Orange, N. J.; W. B. N. Hawk, Elyria, Ohio; W. P. Hayden, Perth Amboy, N. J.; Carl Hegstrom, Perth Amboy, N. J.; Elwood Hendrick; S. T. Henry; Chas. H. Herty, Chapel Hill, N. C.; J. B. F. Herreshoff; B. C. Hesse; Henry D. Hibbard, Plainfield, N. J.; Harold Hibbert; John Wm. Hield; J. F. Hinckley, Newark; Dr. J. M. Hirsh, Chicago; Lea S. Hitchner, Newark, N. J.; Irving Hochstadter; R. A. Holbrook, Chicago; M. L. Holcroft, Chicago; A. P. Hollock; A. Honery, Oak Park, Ill.; M. S. Hopkins, Reading, Pa.; Henry Howard, Brookline, Mass.; E. J. Hubaux; W. F. Hubley, East Orange, N. J.; M. A. Hunter, Troy, N. Y.; H. H. Hurt; J. W. Incusty, St. Louis, Mo.; W. T. Ingraham, Dover, N. J.; Chas. Ingram; Daniel D. Jackson; W. A. James, Buffalo, N. Y.; A. W. Jenkins; W. H. Jennings, Jr., Phoenix, N. Y.; J. E. Johnson, Jr.; Grinnell Jones, Cambridge, Mass.; C. H. Jouet, Roselle, N. J.; J. C. Jurgensen, Lodi, N. J.; E. C. M. Keby, Washington, D. C.; Thos. J. Keenan; John E. Keller, Jr., Litchfield, Conn.; E. J. Kelley; J. S. Kennedy; Chas. W. Kern; J. Kilpatrick, Brooklyn; C. J. Kinzie, Niagara Falls, N. Y.; F. W. Kitterer, Jersey City; H. F. Klemfeldt, Newark, N. J.; W. A. Klipstein; A. F. Kumberger, Philadelphia; P. J. Kurg, Jr., Ithaca, N. Y.; Theo. Kuthier; W. D. Landis, Niagara Falls, N. Y.; Clement L. Le Boutillier, High Bridge, N. J.; Kurt Ledig, Newark, N. J.; L. Lefferts, Brooklyn, N. Y.; X. M. Lehmann, Boston; H. R. Lesser; Wallace G. Levison; F. A. Lidbury, Niagara Falls, N. Y.; Hugo Lieber; Morton Liebschutz, Newark, N. J.; A. T. Lincoln, Troy, N. Y.; G. L. Lindsay; F. M. Linnhard; A. D. Little, Boston; L. I. Loghry, Stoneboro, Pa.; A. Ludwigs, Irvington, N. J.; W. E. Lummus, Boston; J. Lunsman, W. Orange, N. J.; C. N. Manfred; A. S. Manning; O. S. Marckworth, Columbus, Ohio; C. P. Marsh; Gustav Martin, Boston; W. J. Matheson, Newark, N. J.; J. C. Matthews, Arlington, N. J.; Max Mauran, Niagara, N. Y.; A. S. McDaniel, Rochester, N. Y.; James C. McGuire; Parker C. McIlhiney; M. R. McKeown, Pittsburgh, Pa.; Wm. H. Meadowcroft, Great Neck, N. Y.; Wm. S. Miller; H. S. Miner, Gloucester, N. J.; H. K. Moore, Berlin, N. H.; Russel W. Moore; C. B. Morey, Buffalo; Stephen R. Morey; Wm. E. Morrissey; Wm. Roy Mott, Cleveland, Ohio; Emil Mueser, Niagara Falls; J. M. Muir; W. A. Nealy, Boston; E. M. Neil; H. B. Nichols; E. F. Northrup, Princeton, N. J.; L. H. O'Donnell, Jersey City; W. J. Orr, Chicopee, Mass.; P. O. Osterhus, Hackensack, N. J.; Albert B. Pacini, Brooklyn, N. Y.; G. Burke Palmer, Brooklyn, N. Y.; Emanuel Panush; G. G. Pard, State College, Pa.; A. T. Paul; C. A. Peterson, Lancaster, Pa.; J. W. Phelan, Boston; Francis C. Phillips, Pittsburgh, Pa.; Ross Phillips, Niagara Falls, N. Y.; O. W. Pickering, Wilmington, Del.; A. Seton Post; E. Poste, Elyria, Ohio; A. L. Pouleur, New Rochelle, N. Y.; A. L. Price; Chas. W. Price; H. C. Pritham, Bridgeport, Conn.; F. W. Pugsley, Perth Amboy, N. J.; M. B. Punnett, Rochester, N. Y.; Chas. L. Reese, Wilmington, Del.; G. Reuter, Newark; G. A. Richter, Berlin, N. H.; E. G. Rippel, Buffalo, N. Y.; A. D. Risteen, Hartford, Conn.; Hugh Rodman, East Pittsburgh, Pa.; E. F. Roeber, East Orange, N. J.; E. Romanelli, Bloomfield, N. J.; Geo. D. Rosengarten, Philadelphia, Pa.; H. E. Rothwell, Toronto, Can.; Charles F. Roth; G. A. Roush, So. Bethlehem, Pa.; W. E. Rowley; E. de Rozieres, North Brookfield, Mass.; A. T. Saunders, Chicopee, Mass.; Lewis E. Saunders, Niagara Falls, N. Y.; J. F. Schaeffer, Newark, N. J.; A. O. Schiefer, Union Terrace, L. I.; L. B. Schleeder, Trenton, N. J.; Michael Schilling; H. Schlatter, Parlin, N. J.; A. L. Schlesinger, Newark, N. J.; F. E. Schmidt, Mt. Vernon, N. Y.; R. H. Schmidt, Hackensack, N. J.; Dr. P. Schneeberger, Perth Amboy, N. J.; C. M. E. Schroeder, Rutherford, N. J.; Stanley Schubert, Brooklyn; Reach F. Schurtz; F. W. Schwartz, Troy, N. Y.; I. H. Selden, West Orange, N. J.; John Senft, Newark, N. J.; A. F. Shattuck, Detroit, Mich.; Philip Sievering; T. W. Sill, Hudson Heights, N. J.; L. A. Simpson, Douglaston, L. I.; C. R. Sjostrom; W. W. Skiddy; Geo. G. Skinner; F. L. Slocum, Pittsburgh, Pa.; Alexander Smith; Dyer Smith; Harry G. Smith; H. H. Smith, Belleville, N. J.; W. C. Smith, Chrome, N. J.; Irving B. Smith, Philadelphia; J. G. Smith; D. S. Smyth, Danbury, Conn.; F. W. Smither, Washington, D. C.; Walter O. Snelling, Pittsburgh, Pa.; M. G. Snelling, Pittsburgh, Pa.; Henry M. Starkie; Noel Statham; P. V. Stephens; A. Stetson; A. Maude Stewart, Elizabeth, N. J.; G. A. Sticht, Brooklyn, N. Y.; G. C. Stone; Roy Stout, Irvington, N. J.; M. N. Straughn, Washington, D. C.; R. L. Strobridge, Burlington, N. J.; H. C. Stureke, Brooklyn, N. Y.; H. P. Talbot, Boston; Edw. R. Taylor, Penn Yan, N. Y.; Wm. C. Taylor, Corning, N. Y.; C. W. Thompson; John Thornton; Frank J. Tone, Niagara Falls, N. Y.; S. Trepp, E. Orange, N. J.; F. M. Turner, Jr., Toronto, Ont.; W. P. Uhler, Princes Bay, S. I.; W. W. Underwood, Patchogue, N. Y.; M. Utsunomiya, Iyo, Japan; Dr. Carl D. Valli, Grasseli, N. J.; W. S. Vaughan, Roselle, N. J.; Dr. Arno Viehoever, Washington, D. C.; B. R. Von Sholly, Great Neck, N. Y.; J. R. Voorhees, Hawthorne, N. J.; Cornelius D. Vreeland, Upper Montclair, N. J.; C. Wadsworth, Cambridge, Mass.; W. R. Walker; J. C. Walker; R. L. Warburton, Newark, N. J.; W. R. Warren; M. G. Weber, Perth Amboy, N. J.; J. M. Weiss; C. Wendell; G. L. Wendt, Cambridge, Mass.; G. J. Weigand, West New York, N. J.; C. Weisman; M. C. Whitaker; J. O'K. White, Elyria, Ohio; Jonas E. Whitley; C. S. Wicks, Merchantville, N. J.; H. H. Willard, Ann Arbor, Mich.; Chas. F. Winch; J. P. Wintimgleam, Brooklyn, N. Y.; E. E. Wolf; M. A. Wolf, Newark, N. J.; M. G. Wolf; W. J. Wooldridge, Pittsfield, Mass.; W. T. Wyman, Brooklyn; Herbert W. Gepp, Melbourne, Australia; Gilbert Rigg, Palmerton, Pa.; Jokichi Takamine.

Graphite.—The two uses of graphite that seem to have shown the greatest gains in 1914 are its application to lubrication and as a preparation to lessen boiler scale.

Monazite, Thorium and Mesothorium is the title of Technical Paper 110 of the Bureau of Mines. The author is Mr. Karl L. Kithil. This paper describes the properties, occurrence and methods of mining and milling monazite, and methods of preparation of thorium and mesothorium.

A New Electrolytic Method of Sewage Disposal*

BY J. C. OLSEN

The process of sewage disposal described in this paper has been in operation at Elmhurst in New York City for more than a year.

At the plant in New York City a 25,000-gal. unit was in operation for several months and was very thoroughly tested by several chemists, sanitary and electrical engineers. The results were so satisfactory that a 500,000-gal. unit was built and has been in continuous operation since early in April. During this time an average of about 750,000 gal. of sewage has been treated daily, although the unit was constructed for 500,000 gal. For about three months after it was installed, tests were carried out almost continuously by the author, in conjunction for most of the time with Prof. William P. Mason, Dr. C. O. Mailloux and Mr. P. M. Travis. Dr. Mailloux made most of the electrical observations and deductions, while the chemical and bacteriological tests were made by Professor Mason, Mr. Travis and the author, assisted by Mr. William H. Ulrich. The work involved the taking of about 200 samples and their chem-

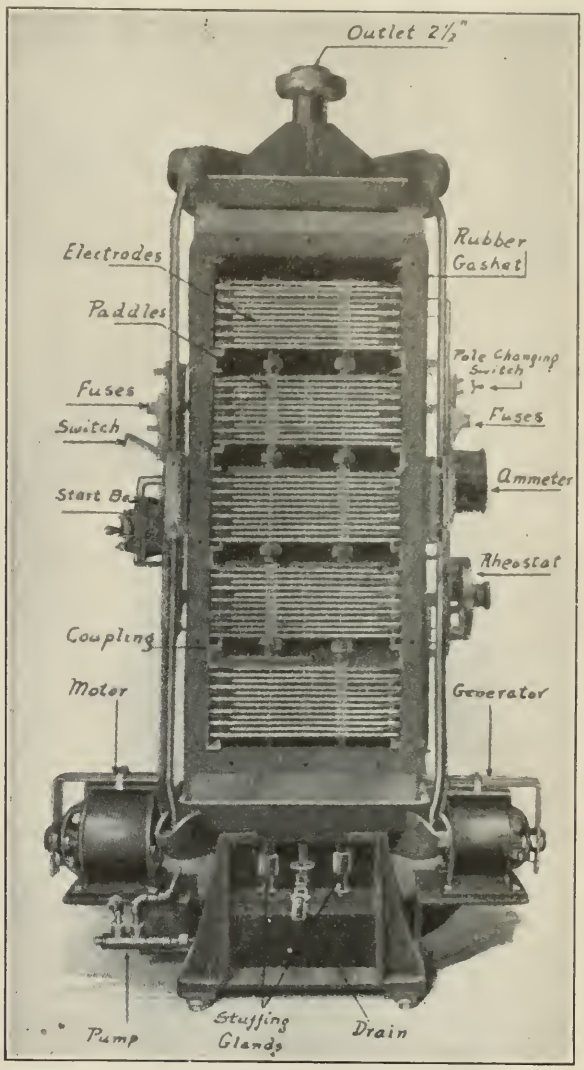


FIG. 1—ELECTROLYTIC APPARATUS WITH DOOR REMOVED, SHOWING ELECTRODES AND PADDLES

*A paper read at the Los Angeles meeting of the American Institute of Chemical Engineers, in joint session with the Southern California section of the American Chemical Society.

ical and bacteriological analyses as well as a very large number of observations of current consumption.

The process and apparatus used was invented and patented by Mr. C. P. Landreth of Philadelphia and will, no doubt, become known as the Landreth electrolytic process of sewage disposal. The electrical purification of sewage has been attempted before in various ways and is or has been in use at a number of localities notably Oklahoma City, Okla., and Santa Monica, Cal.

Mr. Landreth's process seems to be new in that he uses lime together with electrolysis for the treatment of sewage and also in that he uses a much smaller quantity of electricity per gallon than others have employed.

Electricity alone has been used before as well as lime alone, but the combination of these two agents accomplishes what neither of them alone can effect. The Landreth process also employs a very thorough system of agitation.

The process as in use at Elmhurst comprises the following principal stages of operation: (1) screening; (2) electrolytic treatment with addition of lime; (3) sedimentation; (4) filter pressing of sludge.

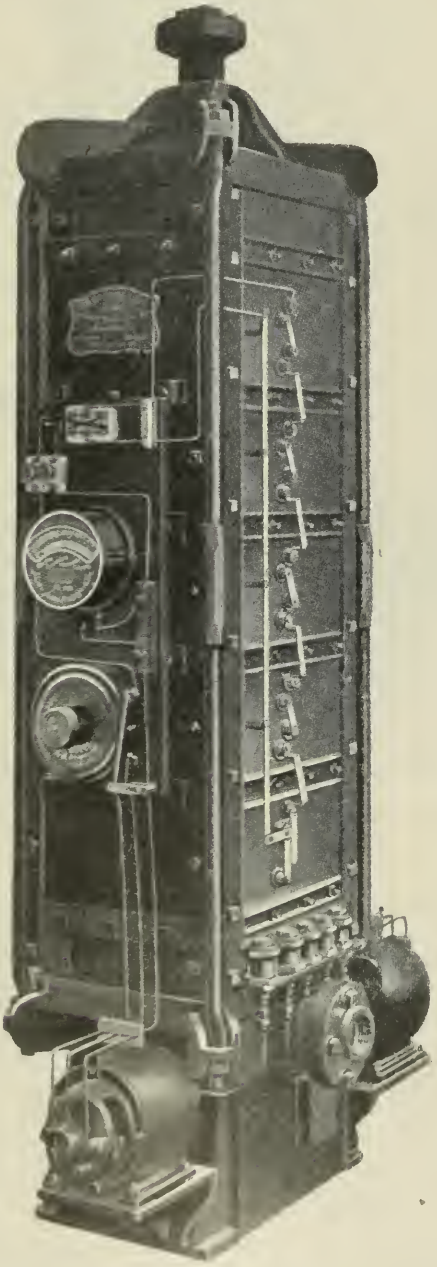


FIG. 2—OUTSIDE VIEW OF ELECTROLYTIC APPARATUS 25,000 UNIT

The raw sewage is delivered by the mains into a receiving well from which it is pumped through quarter-inch screens by means of a centrifugal pump through the electrolytic machine.

The electrolytic machine consists of a horizontal wooden box 23 ft. 3 in. long, 3 ft. in width, and 2 ft. 8¾ in. in depth. It rests upon a masonry foundation 18 in. high. The sides, top and bottom of the box are stiffened by means of angle irons. The top of the box is in two equal sections bolted on, the joint being made tight with a rubber gasket. The top may be removed for cleaning or for the inspection of the electrolytic apparatus.

A series of valves at the bottom serve to remove any sludge which may accumulate in the box.

The sewage to be treated is forced through the apparatus by the pump which takes it from the receiving well and delivers it to the inlet of the apparatus at one end. In passing from the inlet to the outlet (at the other end) of the apparatus, the sewage flows between numerous plates which are placed parallel and close to each other inside the closed box. Consequently the liquid does not flow in one mass, but is subdivided into a large number of relatively thin "sheets." The plates which separate these sheets of sewage from each other also serve as electrical conductors or "electrodes" by means of which electrical currents capable of producing electrolysis are conveyed across the liquid sheets, through the sewage with the result that one side of each liquid sheet is in contact with an "anode" surface, and the other with a "cathode" surface. To insure thorough agitation of the sewage, as it flows in the spaces between the electrode plates, mixers in the form of paddles placed between these plates are rotated in the plans of each liquid sheet.

The plates inside the apparatus are all in a vertical plane, parallel with the sides of the tank, so that the "liquid sheets" of flow between the plates are all vertical. These liquid sheets are not continuous from the inlet to the outlet ends of the apparatus, because the plates are arranged in groups with spaces left between them.

The plates are of iron, and are all of the following dimensions: length, 16 in.; height, 10 in.; thickness, from ¼ in. to 3/16 in. The plates are grouped and assembled in sets, like the plates for an "element" or cell of a storage battery. The plates in each group are all parallel to each other, and they have equal spaces between them (5/16 in. to ⅜ in.). They are held together by bolts, which pass through all the plates, and through the insulating separators between them, and clamp them into a solid unit.

When the groups are in position in the tank, these bolts extend across the tank horizontally and support the plates, which are then all in a vertical position, parallel with the sides of the tank, and occupy the entire available space across the tank. A group contains fifty plates (except in a few cases where the number is one or two less). There are groups at eleven places or divisions in the tank between the inlet and the outlet; and there are two groups at each place, one above the other.

This makes a total of twenty-two groups and (nearly) 1100 plates.

The two bolts just mentioned are also utilized as electrical terminals and conductors for the plates. This is done by insulating the even-numbered plates from one bolt and connecting the odd-numbered plates with it, and doing the opposite for the other bolt.

This is the arrangement used for the groups in the

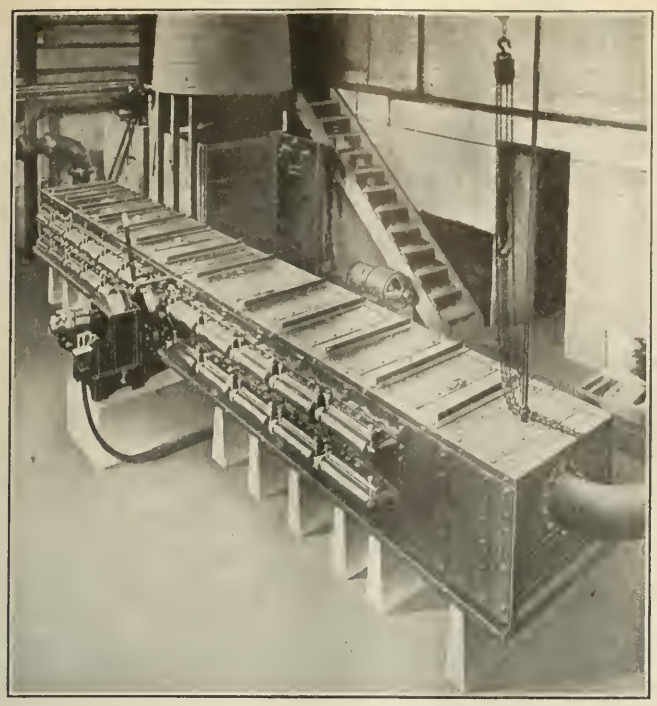


FIG. 3—HORIZONTAL ELECTROLYTIC APPARATUS 500,000 UNIT INSTALLED AT ELMHURST, NEW YORK CITY, MOTOR AND REDUCTION GEARING FOR THE MECHANICAL STIRRERS SHOWN ON LEFT-HAND SIDE OF MACHINE

first section (counting from the inlet) and in the last six sections, or for a total of fourteen groups. In these groups the plates constitute, in each case, an "electrolyzing element" of twenty-five pairs of plates.

In the other four divisions the arrangement is less simple. The fifty plates of each group are not electrically grouped and connected into a single element of twenty-five pairs of plates, but into three elements, each of eight pairs (or more), which are connected in series. It follows that the total number of "elements" in these four sections is twenty-four (*i.e.*, twelve for the four upper groups and twelve for the four lower groups). Adding these to the fourteen elements in the other divisions, the total is thirty-eight elements.

In most of the tests the thirty-eight elements were all connected in a simple series; in one test the nineteen elements in the upper tier were connected by themselves in series, and likewise the nineteen elements in the lower tier; and the two series were then connected in multiple. Various other combinations of series and multiple connection may be made and were made in some of the tests.

When all the thirty-eight elements are connected in series, there is a difference of three to one in the current density at the "large" elements (composed of twenty-five pairs) and at the "small" elements (composed of eight pairs). The same current passes (theoretically) through all the elements, and as the electrode surface is three times greater at the large elements than at the small elements, the current per unit of surface will be only one-third as great at the large elements as at the small elements.

SOURCE OF CURRENT

The current supply required for producing electrolysis is obtained from a direct-current generator of 5-kw. capacity, which is direct driven by an alternating-current induction motor.

The maximum current capacity of the generator is

FIG. 4—HORIZONTAL ELECTROLYTIC APPARATUS INSTALLED AT ELMHURST, SHOWING ELECTRICAL CONNECTIONS ON RIGHT-HAND SIDE OF MACHINE

40 amp. and its maximum voltage is 125 volts. A watt-hour meter was especially connected in the mains between the generator and the switch board for the purpose of the test to enable the direct-current output in watt-hours to be computed for given periods of time in connection with the test.

AGITATION OUTFIT

In addition to the two holes in the electrode-plates for the bolts which serve to hold them together there are two other holes which make openings for the shafts upon which the paddles rotating in the spaces between the electrode-plates are mounted. There are two rotating shafts passing through each group of plates, and each shaft carries forty-nine paddles. This makes ninety-eight paddles per group of plates, or a total of 2156 paddles for the twenty-two groups. The forty-four shafts are supported in bearings mounted in the sides of the tank. They pass through the side of the tank, and are driven by bevel gearing from four horizontal shafts, which receive power from a 3-hp. induction-motor through reduction-gearing.

There is a double reduction-gear by which the speed of the clutch-shaft is reduced to seventy-eight when the motor speed is 1800. The horizontal shafts are geared to run at half this speed, and the paddle shafts are geared to run at half the speed of the horizontal

FIG. 5—SEDIMENTATION TANKS AND OVERFLOW OF PURIFIED SEWAGE

shafts. Hence, if the motor ran without slip the paddle shafts would have a speed of 19.5 r.p.m. Actual test showed that the speed of the paddle shafts was from 18 to 19 r.p.m., according to the "load" on the motor, which at times appears to be relatively heavy, as indicated by the rise of temperature of the motor. The increase in load appears to be due to increased friction between the paddles and the electrode plates, owing to deposits on the plates.

The amount of flow of sewage through the machine was measured by a Venturi indicating and recording meter connected in the discharge pipe leading from the machine to the sedimentation tank.

The milk of lime added to the sewage is prepared by putting quick-lime or hydrated lime in a vat with water and agitating the mixture by electric power, produced by a ½ hp. motor. The electric current supply required for operating the pump motor, the lime vat motor and the motor generator is taken from the street mains through watt hour meters.

METHOD OF OPERATION

The milk of lime is introduced into the sewage in several different ways. A small centrifugal pump operated by an electrical motor was at times used to force the milk of lime into the inlet of the electrolytic machine through a suitable pipe, the amount of flow being regulated by a valve on this pipe. A pipe was also provided by which the milk of lime could be forced into the sewage at the outlet of the machine.

The milk of lime was also at times forced into the sewage through a pipe leading to the inlet of the sewage pump. In the latter case the mixture of the milk of lime with the sewage was affected by the action of the pump.

The electrolyzing current was maintained as nearly constant as practicable, the voltage of the direct-current generator being regulated at the switchboard whenever any variation in the current is observed. The "polarity" of the current was reversed about every hour, with the object of equalizing any chemical action that may be produced on the iron electrodes, and preventing the formation of deposits there. A very considerable drop in voltage occurred on reversing the polarity after which the voltage increased again and after about 15 min. was again normal. The volume of electrical current (amperes) sent through the apparatus, varies with the mode of connection of the electrodes. With all the thirty-eight elements connected in simple series, the current through the circuit was generally maintained at about 30 amp. This is the way in which the apparatus has been principally operated.

On one occasion, the elements in the upper and lower tiers were respectively connected in series, and the two series were connected in parallel. This would give nineteen elements in series, each element being composed of two elements in multiple. The current passing through these series on that occasion was maintained at 40 amp., which was the limit of current output of the direct-current generator.

The voltage of the generator must be equal to the sum of the "voltage-drops" at all points in the entire working circuit, including the leads, the electrolyzing elements, and their connections. The voltage-drop at the electrolyzing elements is the factor which, multiplied by the current (amperes) passing through the elements, gives the electrical energy expended directly upon the liquid. The voltage, or potential difference, per element, depends upon the counter-electromotive force, and the polarization incidental to the electrolysis produced, and upon the electrical resistance of the liquid. These conditions, in turn, depend and are affected by the chemical constitution, the density ("strength"), and the temperature of the liquid.

Theoretically the voltage per element should be the same for all sets of electrodes of the same kind (*i.e.*, having the same number and size of plates, etc.), under the same working conditions. Practically, it is found that the voltage per element varies even with plates of the same kind and size, in consequence of changes in the conditions. Deposits are produced on the plates, which alter the amount of active surface of the electrodes, or decrease the thickness of the sheet of liquid flowing between the plates; and chains and bridges of solid matter may at times form between plates of opposite polarity, causing the current to be shunted in part or even short-circuited entirely. Tests made while the apparatus was in operation show that the voltage per element varies appreciably from such causes.

ELECTROLYTIC ACTION PRODUCED PER UNIT VOLUME OF SEWAGE TREATED

The total quantity of electric current sent through a unit volume of the sewage passing through the machine depends (a) upon the total volume of current or the aggregate sum of the electric currents passing through the elements and (b) the speed of flow of the liquid to the apparatus.

The total quantity of current is equal theoretically to the product of the number of elements connected in series by the current in amperes passing through the series. Thus, with a current of 30 amp. passing through all the thirty-eight elements in series, the total quantity of current would be equal to 1140 amp. on the assumption that there is no loss by leakage or shunting past any of the electrodes in the middle portion of the series.

The length of time that the liquid is subjected to electric action depends upon the length and sectional area of the path through which the sewage flows in passing through the apparatus and the rate of pumping, or the speed of flow through the apparatus.

The time of flow through the apparatus, when in operation, under given actual conditions, was determined by injecting a coloring substance into the liquid at some point ahead of the inlet, and then noting the time which elapsed until the color appeared at the outlet of the apparatus. It was found that when the speed of flow through the apparatus (as indicated by the Venturi flow-meter) was at the rate of 765,000 gal. per day, the time of flow through the apparatus was 1 min. 8 seconds, or 68 seconds. Allowance should be made for the time elapsing while the liquid is passing through the inlet and outlet, and through portions of the apparatus at which there are no electrodes. The actual time that the liquid was passing through the machine did not probably exceed 1 min. (60 seconds).

A rate of flow of 765,000 gal. per day is equal to 531.2 gal. per minute. Allowing for 10 per cent leakage, a current of 1140 (or 1026 net) amperes acting during 1 min. represents 61,560 coulombs. The quantity of electric current applied, in 1 min., to the liquid, is

$$\frac{61{,}560}{531.2} = 116 \text{ coulombs per gallon.}$$

This quantity will obviously vary inversely with the rate of flow. Thus, if the rate of flow were increased to 1,000,000 gal. per day, the coulombs per gallon would fall down to 88; and if the rate of flow were decreased to 600,000 gal. per day, the coulombs per gallon would increase to 148. Under these conditions, and taking into account all causes of variation, the quantity of electric current per unit volume of sewage treated may range, in round numbers, between 80 and

150 coulombs per gallon, or 21 to 40 coulombs per liter. In the tests actually made, the electric current ranged between 19.5 and 40.9 amp. according to connections and other conditions of the tests; and the current per unit volume was from 85 to 169 coulombs per gallon (22.5 to 44.7 coulombs per liter). When extreme and unusual conditions are excluded, the figures are likely to remain within the limits just mentioned.

This quantity of electricity will, theoretically, liberate from 0.00174 to 0.00332 grams or 1.21 to 2.31 cu. centimeters of oxygen per liter of sewage treated.

CURRENT-DENSITY

In fourteen sets of electrode-plates all the plates of the set (forty-eight to fifty in number) are connected electrically so as to make one single electrolyzing element of twenty-four (or twenty-five) pairs of plates. In the other eight sets the plates are connected electrically so as to constitute three electrolyzer elements of eight pairs of plates, and the three elements are connected in series. The theoretical active electrode surface in the "single" elements (of twenty-four pairs) is three times greater than in the "triple" elements (of eight pairs). Hence, with the same current passing through "single" and "triple" electrodes (as when they are connected in single series) the current-density in amperes per square foot of active electrode surface, is only about one-third as great at the "single" as at the "triple" electrolyzer elements.

Each electrode-plate is 16 in. in length and 10 in. in height which gives an active surface of 160 sq. in. on each side, from which must be deducted the loss of active area due to holes in the plates (for the shafts on which the "paddles" are mounted) and to insulating separators. An allowance of 10 sq. in. is made for this deduction, which leaves 150 sq. in. per side. Both sides of each plate are active, except at the two outside plates, which have only one active surface. The active surface of the larger electrolyzer elements (of twenty-four pairs of plates) is $23\frac{1}{2} \times 300$ or 7050 sq. in., equivalent to 48.9 sq. ft. The active surface of the smaller electrolyzer elements (of eight pairs of plates) is $7\frac{1}{2} \times 300$, or 2250 sq. in., equivalent to 15.6 sq. ft.

When all the electrolyzer elements in the apparatus (C-24) were connected in series (making thirty-eight in series), the electrolyzing current is maintained at about 30 amp. The maximum current capacity of the direct-current generator is 40 amp. With an electrolyzing current of 30 amp., the current-density will be equal to the following values:

For large units:
30/7050 = 4.25 milli-amp. per square inch, or,
30/48.9 = 0.61 amp. per square foot.
For small units:
30/2250 = 13.33 milli-amp. per square inch.
30/15.6 = 1.92 amp. per square foot.

With 40 amp. these values would be one-third greater.

For large units:
40/7050 = 5.67 milli-amp. per square inch.
40/48.9 = 0.82 amp. per square foot.
For small units:
40/2250 = 17.8 milli-amp. per square inch.
40/15.6 = 2.56 amp. per square foot.

The range of variation of current-density in round numbers is within the following limits:

For large units:
From 4 to 6 milli-amp. per square foot.
From 6/10 to 8/10 amp. per square foot.
For small units:
From 13 to 18 milli-amp. per square foot.
From 1.9 to 2.6 amp. per square foot.

SEDIMENTATION

In the operation of the process, two sedimentation tanks are used. The sewage, after it has passed through the machine (or through the by-pass, if that be used), is discharged into a flume about 3 ft. wide, which connects with the inlet of the sedimentation tanks in the tank room.

After the sewage has received its dose of lime and has been electrolyzed in the machine, it is passed through the above-mentioned flume in a stream, about 6 in. deep, into two settling tanks (each 82 ft. 6 in. x 20 ft. x 5 ft. 3 in., of about 65,000 gal. capacity, and provided with a baffle at the center rising from the bottom, and also with a deep hanging baffle at the entrance and a skimming baffle at the exit, and from the second of them the settled effluent is finally discharged). These tanks are connected in tandem. The sewage enters the first tank at one end and passes through a gate into the second tank at the farther end. The time for sedimentation in each tank is nearly two hours or four hours for total time of sedimentation, dependent upon the rate of sewage flow. The effluent is discharged from the second tank through a flume by which it is conveyed to the discharge pipe.

It is proper to note that these sedimentation tanks were constructed for sewage disposal by the septic process previously in use at Elmhurst. Suggestions have been made for a new type of sedimentation tank and a model embodying some of them has been constructed, with which it is expected that more rapid and perfect sedimentation will be obtained.

FILTER PRESS

Pipe connections of suitable diameter, leading from the bottom of the sedimentation tank, serve to convey the sludge to a receiving basin in the press room whence it is pumped to the filter press, which is of the Johnson type. Attention should be called to the fact that the filter press is not an essential part of the apparatus as other methods of disposing of the sludge may be adopted.

(*To be concluded in issue of Nov.* 1.)

Alloy Steels*

BY GEORGE L. NORRIS

Steel can broadly be defined as an alloy of iron and carbon that can be forged and rolled. From expediency and necessities of manufacture, certain impurities beneficial or otherwise are present, but not in sufficient amounts to materially alter the characteristics of the pure alloy of iron and carbon.

Under this definition, steel, or as it is now often referred to, carbon steel, is usually within the following maximum composition: Carbon, 1.50 per cent; manganese, 1 per cent; silicon, 0.35 per cent; phosphorus, 0.05 per cent; sulphur, 0.05 per cent.

An "alloy" steel is alloyed with one or more metals, in sufficient amounts to influence or change the characteristics of steel, and still possible of forging or rolling.

The usual steel alloying metals are manganese, silicon, nickel, chromium, tungsten, and vanadium. As these metals will all alloy with each other, it is evident that it is possible to obtain a great variety of alloy steels.

Steel containing upward of 1.50 per cent manganese is not commonly considered an alloy steel, although this

*A paper read before the International Engineering Congress in San Francisco, on Sept. 21, 1915, as part of the Symposium on Iron and Steel, arranged and edited by Prof. Henry M. Howe.

percentage of manganese undoubtedly has some effect on the characteristics of steel. This is due no doubt to the fact that manganese is always present in steel.

The alloy steels are usually divided into two groups: "ternary" steels, with one metal alloyed, and "quaternary" steels, with two metals alloyed. The more complex alloy steels are practically limited to high-speed tool stees.

The general characteristics of alloy steels are high elastic limit and great strength, combined with a high degree of toughness, as compared with the carbon steel with which they are alloyed. The strength and hardness can be enormously increased by heat-treatment (quenching and tempering) and still have the steel retain great toughness.

Alloy steels are not as a rule placed in service in the condition as forged or rolled. The forging and rolling temperatures are usually so high that the steel requires heat-treatment to refine the grain and develop the exact combination of strength, hardness and toughness desired. It is frequently necessary to anneal after forging in order to facilitate machining operations. This, of course, necessitates subsequent heat-treatment.

Most of the alloy steels are of medium or low carbon content. The corresponding simple or carbon steels are only slightly or moderately improved in strength by heat-treatment.

The use of alloy steels in cutting tools dates back nearly a hundred years, although it was not until after 1850 or 1860 that alloy steels for this purpose became firmly established.

With the advent of iron-clad warships began the struggle for supremacy between projectile and armor plate that has been so fruitful in the development of alloy steels. Chromium, nickel, and nickel-chromium steels are largely the result of this struggle.

The publication in 1888 by Hadfield of the results of an extensive research of the alloys of manganese and steel, which resulted in the discovery of a remarkable new alloy steel, marks a period of active investigation into the effect of other metals on steel. The most important of these were the investigations on nickel steels by James Riley in 1889, which demonstrated that a mild open-hearth steel, such as used for structural, general forging and machinery purposes, when alloyed with 3 per cent to 4 per cent nickel had considerably higher elastic limit and tensile strength, with practically the same or greater ductility. One of the earliest and most extensive applications of nickel steel was for armor plate. For many years nickel steel was the principal alloy steel in use.

During this same period referred to, Hadfield made investigation of the effects of silicon on steel, and also a very complete study of chromium steels, which for some time had been used in a small way for springs and special forgings, but principally for tools and armor-piercing projectiles.

The development of high-speed steel about 1900, making it possible to readily machine heat-treated alloy steels, and the advent of the automobile with its demand for superior steel, have brought about the present extensive use and development of alloy steels.

The automobile industry, with its demand for steel of high strength and durability, has been undoubtedly the most important factor in the development of commercial alloy steels, and the largest consumer. Alloy steels are used extensively for transmission gears, and shafting axles, steering levers and spindles, springs, chassis frames, crank shafts, cam shafts, connecting rods, valves and many other parts of automobiles.

They are also extensively employed in forgings for high-speed engines, marine engines, locomotives, electrical machinery, mining machinery, and other mechanical engineering structures.

The use of alloy steels in bridge construction has been limited, but there is undoubtedly a field in long-span bridges for an alloy steel of high strength that can be used in the condition as rolled, preferably, or at most with a simple annealing.

Coincident and having a marked influence on the development of alloy steels, was the discovery of large deposits of vanadium ore in Peru, thus assuring a source of supply at a reasonable cost of this rare metal, which is the most powerful yet discovered for alloying with steel, that is, in small amounts.

The most important of the engineering or constructural alloy steels are those containing nickel, chromium, and vanadium, singly or in combination. With all these steels it is possible, through heat-treatment, to obtain a tremendous range in strength, in round numbers varying from 100,000 to 250,000 lb. per square inch, depending also, of course, upon the size of the section.

It is not possible nor within the province of this paper to go deeply into the technology of alloy steels, but only to briefly describe the principal alloy steels and their characteristics.

MANGANESE STEEL

This steel usually contains 10 per cent to 13 per cent of manganese and approximately 1 per cent of carbon. It is practically non-magnetic and has a peculiar hardness, to which it owes a remarkable resistance to abrasion. It is extremely difficult to machine. It has high strength and toughness, but relatively low elastic limit. With care it can be forged and rolled.

It has found its principal application in castings for crushing and grinding machinery and railroad crossings.

Manganese steel has the peculiar property of being toughened and softened by quenching in water, resembling copper in this respect. All manganese steel castings are subjected to this treatment to remove brittleness.

SILICON STEEL

There are two types of silicon steel, one of which has found some application as an engineering steel. This steel, frequently called silico-manganese steel, is generally covered by the following limits of composition: Carbon, 0.45 per cent to 0.65 per cent; silicon, 1.50 per cent to 2 per cent; manganese, 0.50 per cent to 0.80 per cent.

The manganese is normal, contrary to what is indicated by the name. The principal application of this steel is for automobile springs, and to some extent for gears. It fibers readily through heat-treatment, and is very brittle in the direction at right angles to rolling. It is very sensitive to heat-treatment, and a relatively small variation in annealing temperature after quenching has a strong effect on the results obtained.

The other type of silicon steel contains 3 per cent to 5 per cent silicon, is low in carbon and manganese, and is extensively used for electrical transformer sheets on account of its high permeability and electrical resistance. Structurally, it is weak and has no constructural value.

NICKEL STEEL

Nickel alloys with steel in all proportions, but by far the most important nickel steel, from an engineering standpoint, is the low- and medium-carbon steel with 3 per cent to 4 per cent of nickel, commonly known as 3½ per cent nickel steel.

The presence of manganese in nickel steel is very essential, as it has a marked effect on the mechanical properties. The amount of manganese should range from 0.50 per cent to 0.80 per cent.

This steel has been extensively used since its introduction in 1889, and is a good all-round engineering and structural steel with considerably higher elastic limit and tensile strength than the corresponding carbon steel, and with practically the same degree of ductility.

The low-carbon steel, 0.10 per cent to 0.20 per cent, is used extensively for case-hardening parts. It case hardens more readily than carbon steel and gives a harder casing with a strong, tough, fibrous core.

A great deal of nickel steel with carbon from 0.20 per cent to 0.35 per cent has been used in shapes and plates as rolled and in annealed eye-bars for bridge construction. In this condition, which is not to be recommended for forgings, the following are typical physical properties.

Elastic limit, lb. per sq. in.	45,000 to 60,000
Tensile strength, lb. per sq. in.	80,000 to 100,000
Elongation in 2 inches, per cent.	20 to 15
Reduction of area, per cent.	40 to 25

Annealed nickel-steel forgings have only slight advantage in strength over carbon steel, and consequently are not advantageous either from an engineering standpoint or commercially unless heat-treated. With heat-treatment it gives considerably higher strength than carbon steel, combined with greater ductility or toughness. It does not give as high values as the nickel chromium and chromium-vanadium steels.

Nickel steel rolls and forges readily and machines easily. It develops a very thick, hard scale which is apt to give considerable trouble in drop-forging and is hard on the dies. Nickel steel is also very liable to develop seaminess, especially when made in large heats and cast into large ingots, as is now customary. It requires a larger discard to insure soundness. The use of nickel steel in forgings, and particularly drop-forgings, is falling off in favor of other alloy steels with greater values.

CHROMIUM STEEL

The use of this steel is confined principally to a few specialties and it is not in general use as an all-round engineering steel. One of the principal uses is for balls and ball races. The great mineralogical hardness obtained by quenching is very desirable for this purpose. The steel for this application contains approximately 1 per cent each of carbon and chromium.

Chromium steel is also used for stamp-mill shoes, and in combination with soft steel in laminated plates for construction of burglar-proof safes, and in the same combination in bars for jails.

The low- and medium-carbon types, containing 0.80 per cent or less of chromium, have somewhat higher mechanical properties than the corresponding carbon steel. It is not used to any great extent, other alloy steels being superior, both in static and dynamic strength. Chromium steel is also very liable to crack and check in heat-treatment.

NICKEL-CHROMIUM STEEL

The addition of chromium to nickel steel has a marked effect, greatly increasing the strength and resistance to shock and particularly the mineralogical hardness. It is more difficult to forge and heat-treat and harder to machine, and is also liable to the seaminess frequently present in nickel steel. There are three types of this steel, differing both in the percentage of nickel and chromium, and all with low or medium carbon:

	Nickel, Per Cent	Chromium, Per Cent	Carbon, Per Cent
1st	3.5	1.50	0.25 to 0.45
2d	2.0	1.00	0.10 to 0.45
3d	1.5	0.50	0.10 to 0.45

The first type is used principally for armor plate and armor-piercing projectiles and came into use about 1895, superseding the nickel plates and chromium projectiles.

The other two types were developed by the automobile industry. The second type is largely for automobile forgings. It gives high strength with heat-treatment, has great hardness and good shock and fatigue resisting qualities.

The third type is a largely used all-round engineering steel. It is used for automobile forgings and for a variety of miscellaneous drop-forgings and machine parts. It is an excellent case-hardening steel, carbonizing readily. This type is more tractable in working, heat-treating and machining than the other two. It is also somewhat lower in tensile strength.

VANADIUM STEEL

The addition of small amounts of vanadium, generally under 0.25 per cent, to simple carbon steel or any of the alloy steels increases very considerably—about 30 per cent or more—the elastic limit and breaking strength, without materially affecting the ductility. To an even greater extent it increases the resistance to shock and fatigue.

The vanadium steel which has been up to now most generally used is a chromium-vanadium steel of the following typical compositions:

Carbon, 0.10 per cent to 0.55 per cent.
Manganese, 0.50 per cent to 0.80 per cent.
Chromium, 0.80 per cent to 1.00 per cent.
Vanadium, over 0.15 per cent.

The lower carbon type, 0.10 per cent to 0.20 per cent, is used mainly for case-hardening and is the best steel for this purpose. It carbonizes readily, gives the highest maximum carbon and finest grain. The casing is very strongly coherent to the core, very hard, tough, and strong, and practically free from any tendency to flake or powder. The core is remarkably strong and tough.

The higher limits of carbon, 0.45 per cent to 0.55 per cent, are extensively used for automobile and locomotive springs, giving remarkable resiliency and endurance. It is also extensively used for oil-tempered gears.

The range in carbon from 0.35 to 0.45 per cent is largely employed for crank shafts, locomotive axles, crank pins, connecting rods, hammer piston rods, automobile transmissions and rear axle shafts.

The range from 0.25 per cent to 0.35 per cent carbon is used for automobile forgings of all kinds and a great variety of miscellaneous work requiring the best combination of static and dynamic strength.

As illustrating the wonderful shock and fatigue enduring qualities of chrome-vanadium steel, drop-hammer piston rods of this material are giving many times the length of service of carbon, nickel, and chromium-nickel steel rods.

Vanadium steels have a much wider heat-treatment range than other steels. The desired physical properties can be obtained with a higher draw-back or annealing temperature, which is very advantageous as more completely removing quenching strains, and also as a manufacturing proposition.

Chromium-vanadium steel forges and machines better than nickel-chromium steel, is not as liable to injury in heating for forging, is not so liable to crack or check in heat-treatment and is free from the scamy tendency of steel containing nickel.

Carbon steel with a small percentage of vanadium, from 0.15 per cent to 0.20 per cent, has been used extensively for locomotive-frame castings with great success. The failure of these frames from all causes over a period of nearly ten years has been only a fraction of 1 per cent.

In tool-steel grades this steel has better cutting qualities, hardens deeper and more uniformly, and has remarkable toughness. In what are termed battering tools, chisels, cutters, dies, etc., it gives several times the length of service of ordinary carbon tool steel.

The handicap of high cost of vanadium has almost disappeared, and simple carbon-vanadium steel in the ordinary forging grades will undoubtedly soon become very widely used as an all-round engineering steel, when a better steel than carbon is required. It is remarkably clean and is as easily worked as carbon steel. It is free from the seaminess and ugly scale of nickel steels and the tendency to check and crack of the chromium steels, particularly nickel-chromium.

Tests of carbon-vanadium steel rails in curves are showing about 20 per cent less wear than rails with 0.15 per cent to 0.20 per cent higher carbon, and are also considerably stronger. This difference in wear will doubtless be much greater when the carbon percentage in the vanadium rails is increased to that of the standard rails.

In simple annealed forgings, plain vanadium steel has physical properties well above those specified for heat-treated (quenched and tempered) carbon steel.

This type of vanadium steel has a wider range of quenching temperature than nickel or nickel-chromium steels; and for mechanical properties after heat-treatment is practically on an equality with 3½ per cent nickel or the low nickel-chromium steels in general use, and apparenty has higher fatigue-resisting qualities.

While nickel and chromium interfere seriously with the welding quality of steel, vanadium does not, but on the contrary improves this quality. Vanadium steel wire is in common use for autogenous welding.

TUNGSTEN STEEL

This is principally used for magnets for magnetos and to some extent in hack saws and special tool steels. Tungsten is seldom used in engineering constructional steels, and then usually in combination with chromium.

Table I shows the typical engineering alloy steels and their tensile properties for the same heat-treatment draw-back temperature. This is in all cases 600 deg. C. (about 1100 deg. Fahr.). The specimens in most cases were heat-treated in the form of inch rounds and were machined after treatment.

Table I.—Typical Engineering Alloy Steels

Carbon, Per Cent	Manganese, Per Cent	Nickel, Per Cent	Chromium, Per Cent	Vanadium, Per Cent	Elastic Limit, Lb. Per Sq. In.	Tensile Strength, Lb. Per Sq. In.	Elongation in 2 In., Per Cent	Reduction of Area, Per Cent
.27	.55	...	...	..	49,000	80,000	30	65
.27	.47	...	...	.26	66,000	98,000	25	52
.36	.42	...	...	..	58,000	90,000	27	60
.34	.87	...	...	.13	82,500	103,000	22	57
.45	.50	...	...	..	65,000	96,000	22	52
.43	.69	...	...	.32	96,000	122,000	21	52
.47	.90	...	...	.15	102,000	127,500	23	58
.30	.60	3.40	...	..	75,000	105,000	25	67
.33	.63	3.60	...	.25	118,000	142,000	17	57
.30	.49	3.60	1.70	..	119,000	149,500	21	60
.25	.47	3.47	1.60	.15	139,000	170,000	18	53
.25	.50	2.00	1.00	..	102,000	124,000	25	70
.38	.39	2.08	1.16	..	120,000	134,000	20	57
.42	.22	2.14	1.27	.26	145,000	161,500	16	53
.36	.61	1.46	.64	..	117,600	132,500	16	58
.36	.50	1.30	.75	.16	140,000	157,500	17	54
.30	.50	...	.80	..	90,000	105,000	20	50
.23	.58	...	.82	.17	106,000	124,000	21	66
.26	.48	...	.92	.20	112,000	137,000	20	61
.35	.61	...	1.03	.22	132,500	149,500	16	54
.50	.92	...	1.02	.26	170,000	186,000	15	45

COMPLEX ALLOY STEEL

Practically none of the constructional steels contain three or more alloy metals. The only steel in this class to be considered is what is commonly known as high-speed steel.

Robert Mushet developed and patented about 1860 an air-hardening steel that was very much superior to carbon steel for machining hard material. Mushet steel, as it was known, had about the following composition:

Carbon, 2.00 per cent.
Manganese, 1.75 per cent.
Silicon, 0.75 per cent.
Chromium, 0.40 per cent.
Tungsten, 5.50 per cent.

At the Paris Exposition in 1900 the Bethlehem Steel Company exhibited a new tool steel that took wonderfully heavy cuts at high speeds, the point of the tool heating up to a strong blue color without losing its edge.

This steel, which immediately became known as high-speed steel, was the culmination of the research work carried on for many years by Mr. F. W. Taylor and later published in his monograph "The Art of Cutting Metals." The difference between this steel and Mushet steel is apparent from the following typical composition:

Carbon, 0.60 per cent.
Manganese, 0.20 per cent.
Silicon, 0.10 per cent.
Chromium, 4.00 per cent.
Tungsten, 18.00 per cent.

With this steel, cutting speeds of over 90 ft. per minute were obtained.

Within three or four years it was found that the addition of vanadium to high-speed steel made it possible to still greatly increase the speed and size of cut. At first only about 0.30 per cent vanadium was added, but this has been increased until now 1.00 per cent is practically the standard amount in most high-speed steels, and speeds of 140 ft. and upward per minute have been attained.

Lately the addition of cobalt to high-speed steel has been meeting with favor as still further improving the endurance of the steel. The amount of cobalt generally used is 3 per cent to 4 per cent, with no change in the percentage of the other metals—tungsten, chromium and vanadium.

Pittsburgh, Pa.

Stearic Acid.—The price of this commodity has increased very materially since the beginning of the European conflict. It is largely used in the manufacture of the highest grades of Tripoli and white finish composition, and forms one of the chief ingredients. Due to its continued advancing tendency, it seems very evident that the price of good Tripoli and lime composition must be increased to meet the increased raw material costs. A movement is contemplated by several of the largest manufacturers of Tripoli composition to form a company and erect a rendering plant for the manufacture of stearic acid (from its tallow basis) and in sufficient magnitude to take care of their own and some outside requirements. This would enable the Tripoli manufacturers to offer the best and most uniform product and at the lowest possible cost. Members of the Metal Finishers Equipment Association, which is primarily interested in the good and standardization of the industry, speak very encouragingly of the project and will no doubt give it their enthusiastic support.

The **Federal Dyestuff & Chemical Co.** has been incorporated in Delaware on Oct. 4 as a $15,000,000 concern of New York. The incorporators are Blair Frazier, Newton James, and George A. Harrington, all connected with White & Co., bankers of 30 Pine Street, New York. Further information is not yet available.

The Co-operative Metallurgical Exhibit at the Panama-Pacific International Exposition

BY A. E. WELLS AND G. H. CLEVENGER

The co-operative metallurgical exhibit forms an important part of the United States Bureau of Mines exhibit at the Exposition and is of particular interest to those connected either directly or indirectly with the metallurgical industry. Although this display appears as a Government exhibit and is directly under the management of the Bureau of Mines, it was only made possible by the generous co-operation of the metallurgical industry and the manufacturers of metallurgical machinery and laboratory apparatus who have contributed the funds and equipment necessary for the installation and operation of the exhibit.

The metallurgical exhibit had its inception with the formation of a committee upon metallurgical participation by Charles E. Van Barneveld, Chief of Mines and Metallurgy. This committee consisted of F. G. Cottrell, pyrometallurgy, G. H. Clevenger, hydrometallurgy, and D. A. Lyon, electrometallurgy. Conditions arose which made it impossible to proceed with the plans of the electrometallurgical section of the exhibit, but the work

FIG. 1—EASTERN FAÇADE, PALACE OF MINES AND METALLURGY

of procuring subscriptions from the mining industry and manufacturers for the hydrometallurgical and pyrometallurgical exhibit was at once proceeded with and met with such a ready and liberal response that it was possible to proceed with the plans for the exhibit without delay.

The object of the exhibit has been three-fold. First, to present an attractive and instructive exhibit which would serve to interest the general public in the metallurgical industry. Second, to bring about a closer relationship between the metallurgical industry and the Bureau of Mines and thus enable the Bureau to most effectively assist the industry in the solution of its problems. Third, to begin and, so far as possible, complete the investigation of certain definite metallurgical problems.

The exhibit occupies about 7000 sq. ft. floor area, directly opposite the north entrance of the Palace of Mines, and is in two sections, the east half of the block being devoted to a working display of hydrometallurgical machinery, while the west half of the block is devoted to working laboratories.

The work in the laboratories is under the general direction of Dr. F. G. Cottrell, Chief Chemist of the Bureau of Mines. The chemical research laboratory is under the direction of Dr. L. H. Duschak, Chemical Engineer of the Bureau of Mines. Pyrometallurgical investigations are under the direction of A. E. Wells, Metallurgist of the Bureau of Mines. The hydrometallurgical research work is under the direction of Professor G. H. Clevenger of Stanford University, Consulting Metallurgist to the Bureau of Mines.

Some of the problems under investigation may be enumerated as follows:

(1) The chemistry of roasting sulphide ores in the presence of water vapor and other gases, with the view of devising means of recovering the sulphur. This investigation is being conducted in both the chemical research laboratory and in a small multiple-hearth furnace in the pyrometallurgical laboratory.

(2) Microscopic examination of slags from copper and lead smelting plant, and investigation to determine the possibility of recovery of the metals from the slag.

(3) Investigation of the chemistry and commercial possibilities of the wet thiogen process for the recovery of sulphur from smelter flue gases.

(4) A preliminary investigation of the mechanism of slime settling.

(5) An investigation of the chemistry of the cyani-

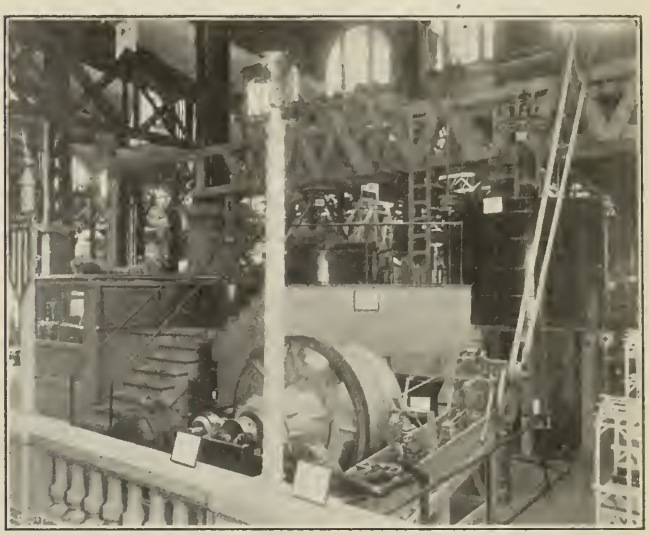


FIG. 2—EXHIBIT OF HARDINGE MILL AND DORR CLASSIFIER AND THICKENER

dation of silver minerals and its bearing upon the treatment of complex silver-gold ores.

(6) Standardization of the methods of analysis and assaying used in hydrometallurgical plants.

(7) The behavior of aluminium compounds in cyanide solutions.

The results of these investigations will be published in the bulletins or technical papers of the Bureau of Mines, and eventually will be available to all who are interested.

Starting at the northeast corner of the block is a model ore sampling mill which is an exact reproduction of the Colorado Springs sampling plant of the Portland Gold Mining Company.

Adjoining this is a $4\frac{1}{2}$-in. Hardinge tube mill, arranged in a closed circuit with a small Dorr simplex classifier. The overflow from the classifier is elevated to a Dorr thickener by means of a Byron Jackson direct-connected centrifugal pump. The overflow from the thickener is returned to the classifier sand and to the tube mill discharge. The underflow from the Dorr thickener is transferred by diaphragm pump to a Dorr agitator.

The pulp, after treatment in the agitator, is pumped by a single stage direct-connected Byron Jackson pump to a Merrill 10-frame, 3 x 4 in., automatic sluicing slime press, where it is washed by solution introduced by the same pump. The press is sluiced by means of a four-stage direct-connected Byron Jackson pump. The clear solution effluent from the press during the filling and washing is delivered by gravity to a 4 x 6 ft. sump tank.

The cloudy solution overflowing from the thickener is delivered by gravity to a second sump from which it is pumped to a Merrill 20-frame 3½ x 3½ ft. automatic sluicing clarifying filter. The clear solution from the clarifying press is delivered by gravity to the sump which received the slime press effluent.

At intervals of from 6 to 8 hr. or more, the deposit on the filter cloths of the clarifying press is removed by sluicing with high-pressure jets of water introduced through a rotating sluicing pipe, this operation being similar to that of sluicing the slime press, except that in the clarifying press the sluicing pipe is located at the center of the plates and frames and rotates in one direction only, whilst in the slime press the sluicing pipe is located at the bottom of the plates and frames and is reciprocated back and forth.

The clear rich solution in the first tank is pumped to a Merrill 10-frame 36-in. agitating precipitation press, the precipitant being delivered into the suction of the pipe between the tank and the pump by a specially designed feeder which can be readily adjusted to feed a varying amount of precipitant. The dry finely powdered precipitant drops from this feeder into a grinding pan or emulsifier, into which is also fed enough water or solution to form an emulsion with the precipitant. The clear effluent barren solution is delieverd to a third sump to be used as a wash for the pulp collected in the slime press. The precipitant is retained in the filter press until it becomes time for a "clean-up."

As it is not feasible to secure a continuous supply of fresh ore in the model cyanide plant, the same pulp is kept in circulation by returning the discharge from the Merrill press to a second Dorr thickener. The overflow from the second thickener is returned to the filter effluent sump, while the underflow is pumped up to the agitator tank by means of a second diaphragm pump. In this way continuous operation is made possible with a minimum amount of material in circulation.

An alternate system of filtration is represented by the Oliver filter. This is the smallest size of standard Oliver filter manufactured, having a drum 3 ft. in diameter by 2 in. in width. A 25 in. to 28 in. vacuum is maintained by a 3½ in. Root rotary wet vacuum pump. Air at 5 lb. pressure from a Baker-Hansen rotary blower is used for the release of the cake and agitation. A 1½ in. Krogh centrifugal pump returns the pulp from the agitator to the Dorr thickener.

This filter is being used in the exhibit for demonstrating the dewatering of flotation concentrate from the Anaconda Copper Mining Company's Washoe plant. The concentrate is fed to the filter from a 4-ft. Dorr thickener at a consistency of one part of water to one part of solids, and is discharged as a ¾-in. cake containing 6 per cent moisture. The discharged cake is carried by belt conveyor to an agitator, where it is broken up and returned to the circuit. In practice this conveyor would probably discharge into a briquetting machine.

The west half of the block is devoted to laboratories, models and charts. In the assaying and general laboratory are installed Braun laboratory crushers, pulverizers, mixers and samples, Abbe ball mill, Tyler Ro-Tap sieve shakers, a complete set of Tyler standard screens, Braun combination gas furnace, gasoline crucible furnace, two muffle assay furnaces for burning crude oil, constant temperature roller agitator, Féry radiation pyrometer, Bristol recording thermometers, and the other accessory equipment necessary in such a laboratory. A balance room, completely enclosed in glass, contains Ainsworth assay and analytical balances and a Keller assay balance. A feature which has proven of unusual interest to the general public in this section is a special chart which shows all the operations of fire assaying.

Adjoining the assay and ore testing laboratory is the pyrometallurgical laboratory. At the present time the equipment of this laboratory consists of the following pieces of apparatus:

(1) A Wedge multiple-hearth roasting furnace, especially designed for experimental work. This furnace has a capacity of 500 lb. of ore per day, and is now being used for experimental work in connection with the distillation of sulphur from sulphide ores, and also for the reduction of barium sulphite and sulphate in connection with an investigation of the thiogen process.

(2) A Monarch tilting furnace. This is being used in connection with the work upon the thiogen process. Bristol indicating and recording pyrometers are used for showing the temperature of the Wedge furnace and the tilting furnace.

(3) A working unit of an electrical precipitation apparatus having a capacity of about 500 cu. ft. of gas per minute. This is complete with transformer, rectifier and precipitation units, and is so arranged that it may be used in conjunction with the experimental Wedge roaster.

(4) A cooling tower, designed by Hunt & Fogg, is being used in connection with the Wedge furnace.

The research laboratory at the other end of the space is surrounded by glass partitions on account of the delicate nature of the work. The experimental work in this laboratory is for the purpose of determining the fundamental chemical principles involved in certain of the metallurgical processes under investigation on a larger scale in the pyrometallurgical and hydrometallurgical laboratories.

The equipment used in this laboratory includes Siemens & Halske indicating and recording pyrometer, a Tycos recording pyrometer and special apparatus designed and constructed in the laboratory. Further equipment includes a complete installation of Leitz micro-metallograph and accessory equipment for microscopic examination of ores, metals and metallurgical products. In connection with this there is also a band saw especially constructed for cutting rock sections, as well as two polishing machines for preparing sections for microscopic examination.

An analytical laboratory, fully equipped with hoods, fume cupboards, gas, compressed air, vacuum and running water, is located adjoining the research laboratory and is used for the analytical work which arises from the various investigations which are being made. Electric furnaces and hot plates of the Electric Heating Apparatus Co. have also been installed.

Facing the main entrance to the exhibit are illuminated charts showing the typical operations of lead and copper smelting. In the same space is a model of an electric precipitation installation, a small working model of a bag house, and also a small model of a Dwight and Lloyd sintering machine. In a glass case is shown a collection of products from both lead and copper smelters, and in another case is shown a complete set of products representative of the Homestake metallurgical practice. Directly back of this space is a small office and conference room.

The funds necessary for the installation and maintenance of the exhibits have been supplied by the following: American Smelting and Refining Company; Anaconda Copper Mining Company; Dorr Cyanide Machinery Company; International Nickel Company; Nevada Mine Operators' Association; Oliver Continuous Filter Company; Phelps-Dodge & Company; Portland Gold Mining Company; the Thiogen Company; W. S. Tyler Company.

The metallurgical Exhibit Fund is deposited with The Union Trust Company of San Francisco, and is administered by the following trustees: F. G. Cottrell, E. B. Braden, Charles E. Van Barneveld, Albert Burch and C. L. Ely.

The following have loaned equipment or donated supplies for the exhibit:

Paul O. Abbe, New York City: Pebble mills, including accessory equipment and cost of installation.

Wm. G. Ainsworth & Sons, Denver, Col.: Assay balance and analytical balances and weights.

Baker-Hansen Company, Oakland, Cal.: Rotary air compressors, rotary vacuum pump, including complete installation.

J. T. Baker & Co., Phillipsburg, N. J.: Laboratory reagents.

Bausch & Lomb Optical Co., Rochester, N. Y.: Microscopes; arc lamp for microscopic work.

Braun Corporation, Los Angeles, Cal., and Braun-Knecht-Heimann Co., San Francisco, Cal.: Laboratory crushers, pulverizers, samplers and mixers, cupel machine, assay furnaces, crucibles, flues and chemicals for assaying, assay chart, roller agitator, apparatus and glassware for ore testing laboratory, including cost of installation.

The Bristol Company, Waterbury, Conn.: Recording and indicating thermometers and pyrometers.

Byron Jackson Iron Works, San Francisco, Cal.: Centrifugal pumps.

Crocker-Wheeler Co., San Francisco, Cal.: Electric motor.

Dorr Cyanide Machinery Co., New York City: Classifier for fine ground ore, continuous thickener, continuous agitator, including accessory equipment and complete installation.

Dwight & Lloyd Sintering Co., New York City: Model sintering machine.

Edison Storage Battery Supply Co., San Francisco, Cal.: Storage battery.

Electric Heating Apparatus Company, New York City: Electric hot plates, electric crucible furnace.

Charles Engelhard, New York City: Recording and indicating pyrometers.

Guernsey & Company, San Francisco, Cal.: American Blower Company exhauster.

Hardinge Conical Mill Company, New York City: Conical tube mill, including complete installation.

H. W. Johns-Manville Co., San Francisco, Cal.: Fireproof cements and asbestos.

Krogh Pump Manufacturing Co., San Francisco, Cal.: Centrifugal pumps.

Keller Manufacturing Co., Salt Lake City, Utah: Assay balance.

Ernst Leitz, New York City: Micro-metallograph and automatic arc lamp, microscopes.

Mammoth Copper Mining Co., Kenneth, Cal.: Operating model of bag house.

Merrill Metallurgical Company, San Francisco, Cal.: Automatically sluiced filter press, automatically sluiced clarifying filter, agitating precipitation filter, zinc dust feeder and emulsifier, including complete installation.

Monarch Engineering Co., Baltimore, Md.: Tilting furnace.

Oliver Continuous Filter Co., San Francisco, Cal.: Continuous filter, including complete installation.

Pacific Tank and Pipe Company, San Francisco, Cal.: Redwood tanks, including installation.

Portland Gold Mining Co., Colorado Springs, Col.: Operating model of sampling mill.

P. H. & F. M. Roots Co., Connersville, Ind.: Rotary vacuum pump.

E. H. Sargent Company, Chicago, Ill.: Water still.

I. C. Smith, Los Angeles, Cal.: Air compressor.

Spencer Lens Company, Buffalo, N. Y.: Microscopes.

H. B. Squires Manufacturing Co., San Francisco, Cal.: Cutler-Hammer air-pressure control apparatus.

Taylor Instrument Companies, Rochester, N. Y.: Féry radiation pyrometer, thread recorder and thermoelement.

W. S. Tyler Company, Cleveland, Ohio: Ro-Tap sieve shaking machine and standard sizing screens.

Union Oil Company of California, San Francisco, Cal.: All fuel oil, gasoline distillate, lubricating oils, used in the exhibit during the Exposition.

Utley Wedge, New York City: Mechanical roasting furnace.

Fred. Ward & Sons, San Francisco, Cal.: Carborundum grinding powder.

Western Precipitation Company, Los Angeles, Cal.: Electrical precipitation apparatus and model of installation.

Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.: Electric motors.

G. E. Witt Co., San Francisco, Cal.: Pressure reducing valve.

The United States Geological Survey have co-operated through the detailing from their staff of F. B. Laney and E. S. Bastin, who have charge of the microscopic and mineralogical work.

The University of Utah has detailed Prof. R. H. Bradford and Fellow H. J. Morgan to co-operate in the investigations which are being made.

Prof. Welton J. Crook of the South Dakota State School of Mines has contributed his services in connection with some work upon the cyanidation of silver minerals.

The following men have been detailed by the United States Bureau of Mines, largely from the San Francisco Station: G. H. Clevenger, consulting metallurgist; F. G. Cottrell, chief chemist; L. H. Duschak, chemical engineer; W. Freeman, junior chemist; R. E. Head, skilled laborer; G. N. Libby, assistant metallurgist; A. E. Wells, metallurgist; E. H. Zeitfuchs, junior chemist.

The following men have been employed with the co-operative fund: C. E. Brandt, analytical chemist; R. Buhman, assistant chemist; H. S. Coe, assistant metallurgist; H. B. Jordan, assayer; G. A. Linhart, analytical chemist; E. A. Madison, draughtsman; E. I. Oberlightner, laborer; K. Pyle, assistant metallurgist; H. W. Young, assistant metallurgist.

Graphite brushes for use upon commutators are being furnished by the Joseph Dixon Crucible Co. of Jersey City. It has been found that they are free from grit and are self-lubricating.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in March, 1915, was 63. The total quantity of ore milled during that period was 2,123,465 tons. There were 9745 stamps in operation, with an average duty of 9.22 tons per 24 hours. Tube-mills in commission numbered 309. The yield for the month was 676,221 fine ounces gold. The working profit per ton milled was only 8s. 4d., as compared with 9s. in February, 1914.

Vulcanized Fibre

BY CHARLES ALMY, JR.

Despite the fact that the annual production of Vulcanized Fibre in this country exceeds 15,000,000 lb., comparatively little is known either of the method of manufacture or the properties of this widely used material. Books on Industrial Chemistry or Cellulose Products, as a rule, dismiss the subject with a few words, often inaccurate or misleading, and give in many cases the impression that Vulcanized Fibre is still largely in a visionary stage, interesting chiefly from the theoretical standpoint.

FIG. 1—MACHINE TURNING OF VULCANIZED FIBRE SHOWING ITS TOUGHNESS

The purpose of this brief article is to explain in a few words the main facts regarding its manufacture and to outline some of the properties that have made it so widely useful to the engineering professions.

Vulcanized Fibre was invented by an English chemist named Taylor about the year 1869, but its commercial development dates from 1873 when the American Vulcanized Fibre Company was established in Wilmington, Del. Although the original patents included the use of sulphuric or nitric acids with or without the addition of various metallic salts, the process as practised to-day is confined to the action of zinc chloride on an all cotton cellulose paper, unsized and unloaded.

This paper is passed over heated cylinders through a bath of zinc chloride maintained at about 70 deg. Baume and 40 deg. C., depending upon the quality of the paper and the atmospheric conditions. It is then rolled up over large heated drums to the desired thickness, the zinc chloride hydrolyzing the cellulose and gelatinizing the surface to such an extent that the paper unites together and forms an almost homogeneous mass. Fibre tubes are made in a similar manner by substituting for the large drums, mandrels of the proper size to give the desired inside diameter.

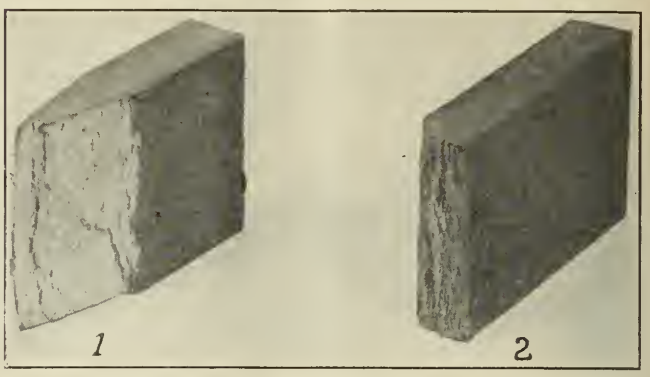


FIG. 3—TENSILE TEST—NO. 1, SP. GR. 1.25, FRACTURED AT 8650 LB. PER SQUARE INCH—NO. 2, SP. GR. 1.37, FRACTURED AT 12,250 LB. PER SQUARE INCH

The "green fibre" is then washed in zinc chloride baths of progressively diminishing concentration until it is commercially pure, i.e., contains less than 0.15 per cent chlorine. This process is of necessity very slow, and any attempts to expedite it are apt to result in an inferior grade of fibre or in blisters due to the increased osmotic pressure. One-quarter inch fibre, for instance, requires three to four weeks for washing, and 2-in. fibre six to eight months. The wet pure fibre is dried at a temperature of 40 deg. to 60 deg. C., after which it is pressed and usually calendered.

The finished product which has shrunk to one-half its original thickness is a homogeneous, tough, horn-like material which can be readily machined, threaded, embossed, etc., and which can be given a high polish. Fig. 2 shows cross sections of two pieces of gray vul-

FIG. 2A—GRAY VULCANIZED FIBRE, SP. GR. 1.45

FIG. 2B—GRAY VULCANIZED FIBRE, SP. GR. 1.20

canized fibre photographed across the laminations at a magnification of about 150 diameters, and illustrates very forcibly the homogeneity of the material.

Vulcanized Fibre is not waterproof, but is not injured by immersion in water, either hot or cold, and on re-

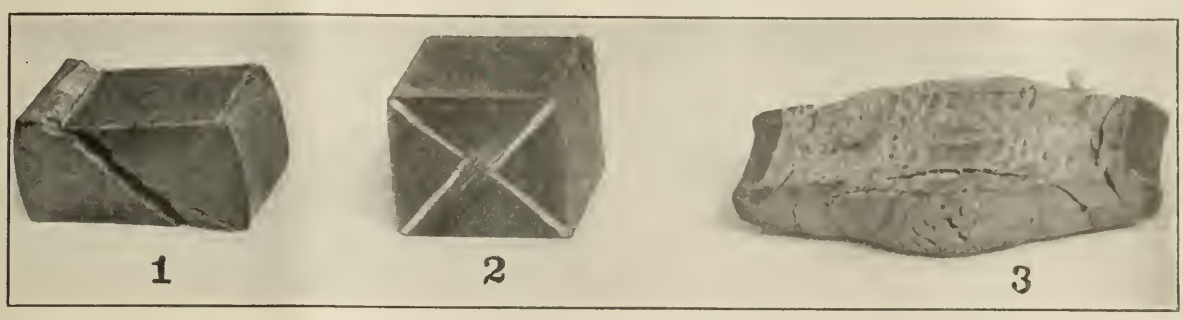


FIG. 4—COMPRESSION TESTS—NO. 1, 38,000 LB. APPLIED ON NATURAL FACES OF 1-IN. FIBRE CUBE—NO. 2, 9000 LB. APPLIED ON EDGE OF 1-IN. FIBRE CUBE—NO. 3, 90,000 LB. APPLIED ON EDGE OF 1-IN. CUBE AS IN NO. 2—NOTE HOMOGENEITY AS SHOWN BY 45-DEG. FRACTURE

drying resumes its original dimensions and properties. Neutral salts are also without any harmful effect, but most mineral acids in time cause disintegration. Organic solvents, such as ether, carbon tetrachloride, etc., and all oils are absolutely without effect on fibre, and are not absorbed in the slightest degree.

The mechanical and physical properties may be varied between fairly wide limits by proper manipulation of the chemical treatment and by varying the quality of the original paper. This fact is little appreciated by the public, and, in fact, only too little appreciated by some of the fibre manufacturers themselves. Consequently a man believing that "fibre is fibre" may purchase a grade absolutely unsuited for his particular needs, and without further investigation conclude that all fibre is worthless to him. To illustrate this point more strongly, we give in Table I the properties for two samples of material both of which sell under the name of Vulcanized Fibre.

FIG. 5—SECTION OF TRACK 4400 FT. IN LENGTH AT McKEE'S ROCKS, ON THE P. & L. E. R. R., WHERE 3000 STEEL TIES WERE INSULATED WITH AMERICAN VULCANIZED FIBER SHIMS THAT HAVE LASTED OVER FIVE YEARS

TABLE I—PROPERTIES OF TWO KINDS OF VULCANIZED FIBRE

	No. 1	No. 2
Thickness	⅛ in.	⅛ in.
Specific gravity	1.100	1.480
24 hours' absorption of water	70%	25%
Chlorine content	0.20%	0.03%
Hardness by scleroscope	25	50
Shearing strength, lbs. per sq. in.	9,000	13,000
Crushing strength, lbs. per sq. in.	33,000	43,000
Tensile strength, lbs. per sq. in.	8,000	13,000
Breakdown voltage	12,500	50,000

At a glance it will be seen that there are great differences in the properties of the two samples, and that the purchaser of fibre must take care how and where he buys in order to be sure that the manufacturer is able to and actually does give him the grade best adapted to his purposes.

Vulcanized Fibre is used in all kinds of electrical insulation; in trunks, roving cans, waste baskets and similar receptacles; and in a great variety of mechanical parts such as gears, valves, washers, bushings, etc. One of its principal applications is in railroad insulation for automatic block signals, shims, etc. Fig. 5 shows an installation of the latter and illustrates the extreme durability of the material. Vulcanized Fibre gears are noiseless and oil-proof and on account of their toughness and elasticity will outwear two or three sets of brass gears. Vulcanized Fibre valves have given continuous service for over three years in feed-water pumps, pumping hot water at 212 deg. Fahr., against 150 lb. pressure, and are far superior to rubber or composition valves for water or any neutral solution.

The tensile strength of Vulcanized Fibre which is three times that of leather, and its high dielectric strength of 200-400 volts per mil, are constantly leading manufacturers as they become more familiar with this interesting material, to adopt it for new uses, and it is hoped that this article may prove of value by suggesting to some puzzled engineer the answer to the frequent query, "What material can I use?"

Research Laboratory,
American Vulcanized Fibre Co.,
Wilmington, Del.

The **Titanium Alloy Manufacturing Company** has prepared an illustrated booklet entitled "How Titanium Bronze Is Produced." It is profusely illustrated with photographs of the various departments of its works.

The Electrolysis of Copper Sulphate Liquors, Using Carbon Anodes*

BY LAWRENCE ADDICKS

Through the courtesy of Dr. James Douglass, I am permitted to give the results of quite an extended research conducted at Douglas, Ariz., on the possibilities of electrolytic recovery of copper from liquors resulting from sulphate leaching.

Starting with sulphide copper ores or concentrator products therefrom, which was the particular case under consideration, the simplest form of the proposition is to make sulphuric acid from concentrates by the usual roasting procedure, use this for leaching, electrolyze with lead anodes and precipitate upon iron sufficient of the liquor to maintain a reasonable degree of purity in the electrolyte. Such a method is commercial when there is no serious competition by other processes, as where concentrator tailings are very rich in values or where some local handicap to smelting exists, or where there is a profitable market for a surplus of sulphuric acid.

A very different way of attacking the problem was the old Siemens-Halske process, where ferric sulphate was used for the direct consumption of sulphides, the resulting ferrous-cupric sulphate liquor being electrolyzed in a diaphragm cell, obtaining a copper cathode and regenerating the ferric sulphate at the same time. This failed, partly due to the non-existence of a satisfactory diaphragm and partly to the shortcomings of the leaching agent.

Then Tossizza attacked the question by applying the long known action of sulphur dioxide gas as a depolarizer, introducing it directly into the cell, making sulphuric acid in accordance with the inclusive reaction.

$$CuSO_4 + SO_2 + 2H_2O + \text{current} = Cu + 2H_2SO_4$$

and reducing the voltage in proportion to the energy of oxidation at the anode. The direct use of sulphur dioxide as a depolarizer is undesirable for three reasons: (1) The escaping gas makes the atmosphere of the cell room unbearable and the ventilating problem, while perhaps not insurmountable, would be a very serious matter; (2) the gas escapes so readily from a warm liquor in motion that the consumption would be prodigal and there are limits, even though rather liberal ones, upon the quantity available; (3) it is a difficult matter to obtain a sufficient absorption for efficient depolarization, using roaster gas, unless compressors or other complications are resorted to.

The research work finally developed a process based upon the depolarizing value of ferrous sulphate, using a carbon anode, the sedative value of aluminium sulphate (U. S. patent No. 1,138,921) thereby restraining the redissolving of the cathode copper, and the reduction of the ferric sulphate by sulphur dioxide outside of the cell room. It is the purpose of this paper to discuss the various factors involved in this scheme of procedure.

While it is not possible to divorce entirely these different factors, for clearness' sake they will be taken up individually as follows:

1. Circulation and agitation.
2. Anodes and depolarization.
3. Cathodes and corrosion.
4. Sulphur dioxide and reduction of ferric sulphate.
5. Efficiencies.

Circulation and Agitation

In any electrolytic process the constituents of the electrolyte taking part in the oxidation at the anode and the corresponding reduction at the cathode must be continually supplied at the electrodes by some method of circulation at a rate sufficient to satisfy the demands of the current at the density employed. If this is not done the voltage will rise until the next reaction in line occurs, or if the voltage is limited, the current will fall, or flow spasmodically. In our particular case ferrous sulphate must be supplied at the anode fast enough to take up the oxygen released and copper at the cathode in sufficient quantity to prevent the liberation of hydrogen or precipitation of impurities. A relatively low rate of circulation suffices at the cathode if the liquor is reasonably rich in copper sulphate, as demonstrated in ordinary refining with a soluble anode. At the anode, on the other hand, a violent circulation is necessary, and this is best obtained by agitation with compressed air, apart from the relatively low circulation necessary for replenishment.

The reason for this behavior of the anode is doubtless due to the fact that a gas is liberated on a rather rough surface and more or less of a mechanical scouring action is necessary as well as a sufficient concentration of ferrous iron. In ordinary refining work the liquor is circulated at a rate which displaces the contents of a cell in several hours. In this work, at a current density

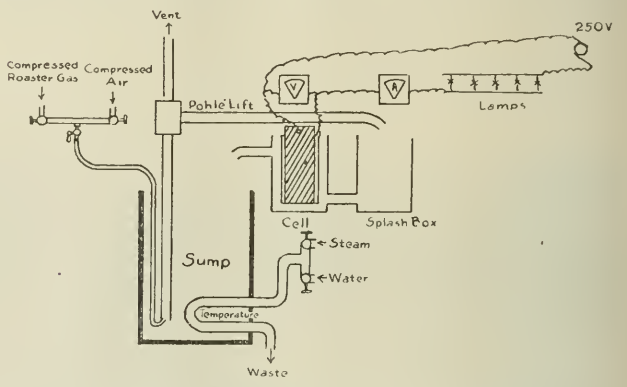


FIG. 1—CELL ARRANGEMENT FOR VOLTAGE TESTS

Carbon anode, 3½ x 4 in. (9 x 10 cm.). Copper cathode, 4 x 4 in. (10 x 10 cm.). Electrodes 1 in. apart (2.5 cm.).

of 4 amp. per square foot (44 per square meter) a relatively low rate of circulation proved adequate, but at 8 amp. per square foot (88 per square meter) the contents of the cell, in small scale experiments, had to be displaced every thirty seconds, and at 16 amp. every twenty seconds, in order to obtain voltages indicating satisfactory depolarization, although these were readily reached by stirring or agitation. Any method of agitation which affords rapid movement of the electrolyte over the face of the anode may be used, but the introduction of compressed air at the bottom of the cell seemed the most practical application.

Fig. 1 is a diagram of the apparatus first used in making these experiments. As the first runs were purely voltage determinations, agitation was dispensed with, a stirring rod being vigorously used at the time a reading was taken. Compressed roaster gas was at first used in the Pohlé lifts, but later air was substituted. After complete voltage records had been obtained for varying current density, composition of electrolyte, temperature, etc., the question of current efficiency was studied, several cells being connected in series and compressed air being introduced through a perforated false bottom in each cell.

Finally large cells were operated, using 600 amp., as shown in Fig. 2, and compressed air was introduced at the bottom of each cell, through a 1½-in. (3.8-cm.) lead pipe, coiled in a spiral and perforated at regular intervals with eighty 3/64-in. (1.2-mm.) holes. Measurements showed that the pressure necessary started

*A paper read at the San Francisco meeting of the American Electrochemical Society Sept. 17, 1915.

FIG. 2—FULL SIZE CELLS

FIG. 4—ANODE PARTS FIG. 5—COMPLETED ANODE

barely above that of submergence or about 1½ in. (3.8 cm.) of mercury. Then as these holes gradually became choked by crystals or sediments, the pressure rose to about 3 in. (7.6 cm.) of mercury. This would take several hours. Then steam was introduced into the air system for several minutes, which fully cleared it. The quantity of air used was about 500 cu. ft. (14 cu. m.) an hour, and as each cell deposited over a pound (453 gr.) of copper an hour, it will be seen that the power for compressing this air was very small.

The general plan of operation adopted was, therefore, a circulation sufficient to replenish the liquor at a rate which would hold the anode oxidation product—ferric sulphate—at a concentration which would not seriously corrode the cathode, and compressed air agitation sufficient to obtain a minimum voltage by depolarization. An idea of these effects may be obtained from Fig. 3, which shows the voltages in one of the small cells with and without agitation for different current densities and temperatures. It will be noted that rising temperature assists the depolarization while rising current density impedes it.

Anodes and Depolarization

Three commercially possible materials are to-day available for use as insoluble anodes in sulphate liquors:

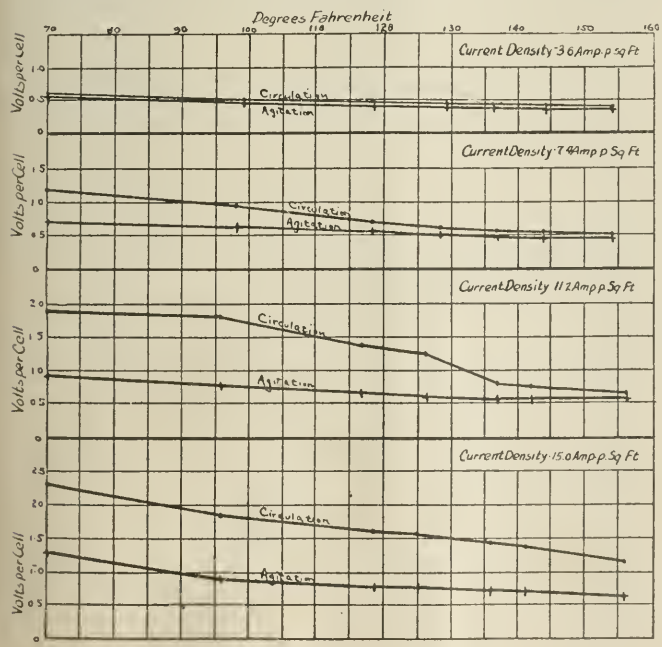


FIG. 3—EFFECT OF AGITATION UPON CELL VOLTAGE

Electrolyte—3.7 per cent Cu, 2.0 per cent Fe, 4.3 per cent Al_2O_3, 4.2 per cent H_2SO_4.

Lead, magnetite and carbon. There are two objections to lead, viz., it does not work at low cell voltages even in the presence of depolarizers, and its life is more or less limited, due to the flaking off of the sulphate and peroxide formed on its surface.

Magnetite is fragile and expensive and it remains to be seen whether it will hold its own in large-scale work. The showing made at Chuquicamata will settle this point.

Carbon has been used for many years as an anode in chloride electrolytes and has given satisfactory service. In many of these cases free chlorine gas has been evolved at the anode, so that the disintegration of the carbon conglomerate in sulphate solutions must be due to the chemical properties of the oxygen formed, rather than to any physical attack. We know that charcoal, for example, has the property of absorbing large volumes of gases and we find that oxygen evolved at a carbon anode will react markedly with depolarizing agents, while oxygen liberated in the same way at a lead anode gives but partial response. It seems likely, therefore, that something akin to ozone is formed at the surface of the carbon anode, and that in the absence of substances susceptible of more ready oxidation, the carbon itself or its more or less carbonized binding material is oxidized and the anode breaks down.

The early work done with electrolytes weak in either sulphur dioxide or ferrous sulphate, showed a very decided softening of the surface of the anode. The later work, after ferrous sulphate was definitely adopted as the depolarizing agent, and a minimum of 1½ per cent ferrous iron kept in contact with the anode by agitation, showed no sign of any deterioration of the anode after several months' use. Nearly all of the work was done with Acheson graphite slabs, but some tests were made with baked carbon slabs and as far as these tests went, no difference was found in the behavior of the two.

The construction of a practical anode out of the ½ x 4 inch (1.25 x 10 cm.) slabs used gave some trouble. After several trials the design shown in Figs. 4 and 5 was developed and gave satisfactory service. The carbon strips were first trued up and the necessary holes drilled. Then they were electroplated with a thin film of copper at the upper end and the copper contact strips attached with copper bolts and nuts. The exposed copper parts were then given a coat of asphaltum paint and a lead apron burned around the entire upper end. This construction prevented the electrolyte from reaching the copper parts and dissolving them either chemically or electrolytically and the voltage drop between bus bar and active anode surface was negligible.

When a piece of carbon and a strip of copper are immersed in an acidulated copper sulphate solution, a voltmeter indicates an open circuit voltage of 0.29 volt,

the carbon being, of course, electro-negative to the copper. This counter e.m.f. has, therefore, to be overcome when using carbon as an anode. The data given in Fig. 3 can be rearranged to show this; this is done in Fig. 6, and brings out clearly the effect of agitation, temperature and current density. No attempt has been made to measure actual polarization voltages or figure the theoretical voltages possible, but the solid lines in this diagram represent the actual voltages obtainable under corresponding working conditions. The liquors used in many of these measurements contained a few hundredths of a per cent of free sulphur dioxide, but it is not believed that this has any bearing on the voltages obtained. All percentages by analysis given in this paper represent grams per 100 c. c., except when measuring the percentage of sulphur dioxide in roaster gas, which is stated by volume.

Next a series of investigations was undertaken on the effect of varying quantities of free acid, iron and alumina in the electrolyte upon the voltage obtainable. In order to keep this paper within reasonable length, but a few representative diagrams will be given from the great number of measurements made and tabulated. Fig. 7 shows the general relation between power and voltage and current efficiency in the electrolysis of cupric sulphate, for convenience in considering the possible recovery per kw.-hr. under various conditions.

Figs. 8 and 9 show the effect of varying the quantity of free sulphuric acid in the electrolyte at a constant temperature of 120 deg. Fahr. (49 deg. C.). As increasing temperature was found of material assistance both in reducing the ohmic resistance of the cell and in rendering efficient depolarization more easily obtainable, a cell temperature of about 115 deg. Fahr. (46 deg. C.) was determined upon when large scale work was taken up. Too high a temperature, on the other hand, increased cathode corrosion, a matter which will be discussed later on. Fig. 10 shows the working voltages obtained with varying acidity in large scale work. It is evident that the acid assists somewhat in the mechanism of depolarization and lowers the resistance of the electrolyte, but that there is no warrant for carrying the high percentage of acid used in regular refining work. The enormous quantity of salts present in the electrolytes used is doubtless the cause of this difference. Most of the work was, therefore, done at an acidity of not less than 4 per cent. Too high an acid content impeded the solution of sulphur dioxide, as will be shown later. The temperature in Fig. 10 was 119 deg. Fahr., the electrolyte contained 4.3 per cent Cu, 3.5 Al_2O_3, 2.4 Fe.

Next the effect of aluminium sulphate was taken up and the results obtained at a temperature of 120 deg. Fahr (49 deg. C.) with varying current densities are shown in Fig. 11, and similar data for a fixed current density with different temperatures in Fig. 12. These two sets of curves have been selected as representative of the general effect alumina has of interfering with depolarization. It was found in regular work that 4 per cent was the maximum which could be carried in the electrolyte without excessive voltage, disproportionate agitation or the production of soapy froth. On the other hand, it is desirable to carry as much as possible on account of its restraining effect upon cathode corrosion. It may be said here that a current density of 13 amp. per square foot (143 per sq. m.) was decided upon as causing about as rapid a production of oxygen at the anode as could be properly handled by the depolarizing agent. Alumina also reduces the absorbing power of liquor for sulphur dioxide.

Next the effect of ferrous sulphate was studied. Fig. 13 shows that in the absence of agitation the voltage decreases in proportion to increasing concentration of ferrous iron but that except at high temperatures even

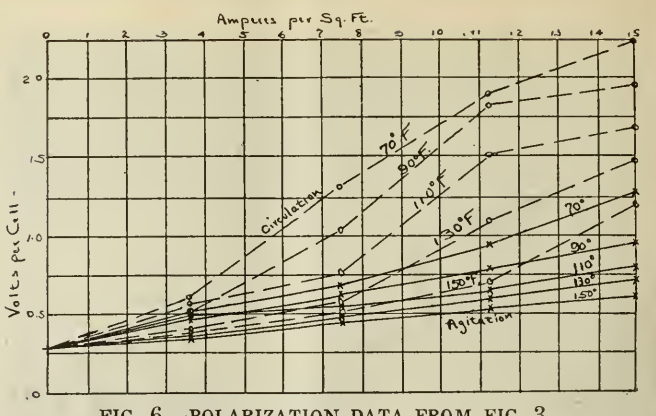


FIG. 6—POLARIZATION DATA FROM FIG. 3

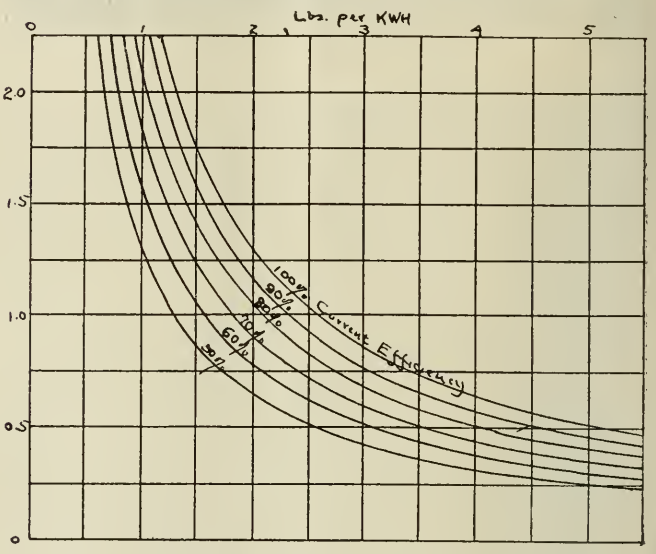


FIG. 7—POUNDS COPPER PER KILOWATT-HOUR

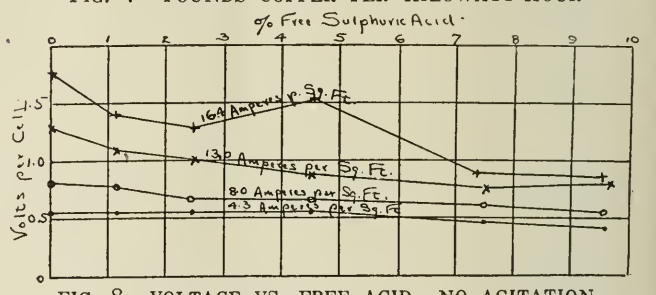


FIG. 8—VOLTAGE VS. FREE ACID—NO AGITATION

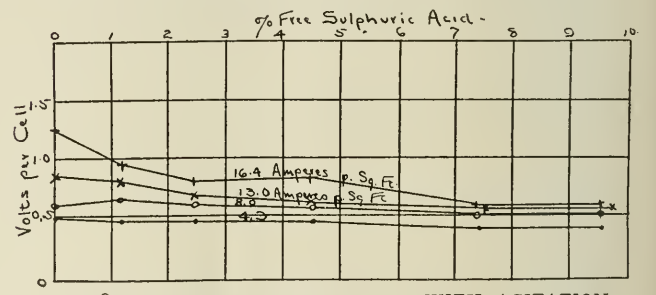


FIG. 9—VOLTAGE VS. FREE ACID—WITH AGITATION

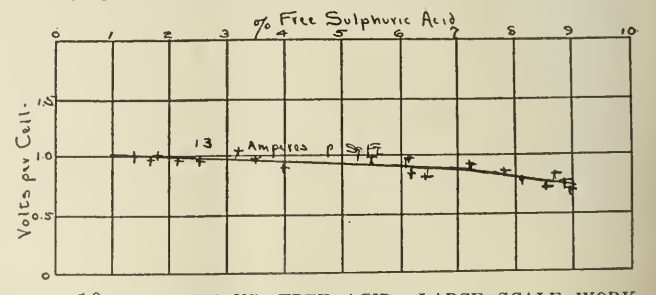


FIG. 10—VOLTAGE VS. FREE ACID—LARGE SCALE WORK 119 DEG. FAHR.

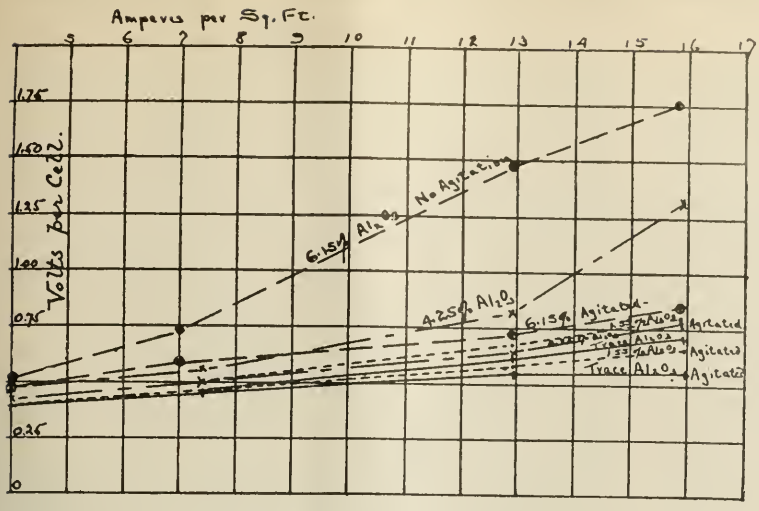


FIG. 11—VOLTAGE VS. ALUMINA

2.5 per cent Cu, 3.3 per cent Fe, 4.3 per cent H_2SO_4, 120 deg. Fahr. (49 deg. C.).

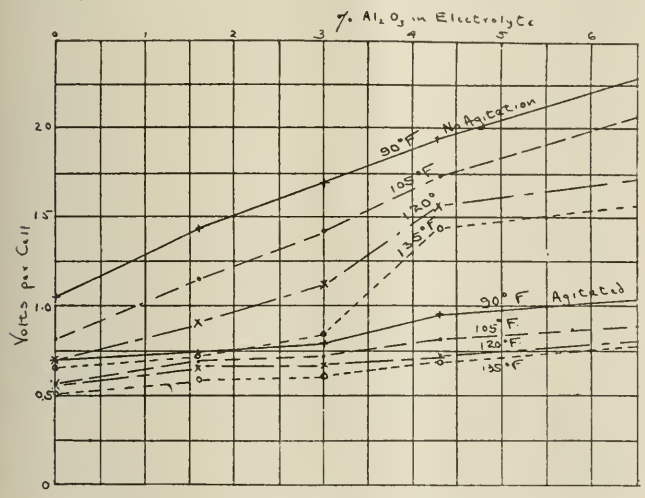


FIG. 12—VOLTAGE VS. ALUMINA

3.1 per cent Cu, 2.4 per cent Fe, 4.0 per cent H_2SO_4, 15.7 amp. per square feet (173 per square meter).

very concentrated solutions give but partial depolarization. On the other hand, with agitation, the voltage drops immediately as iron is introduced, to a minimum

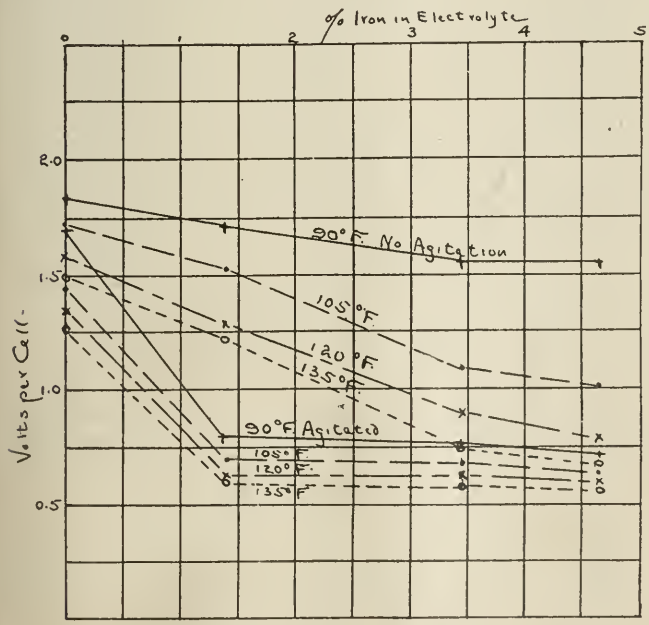


FIG. 13—VOLTAGE VS. IRON

2.6 per cent Cu, 4.4 per cent Al_2O_3, 4.2 per cent H_2SO_4, 12.5 amp. per square foot (137 per square meter).

which is practically unaffected by further additions. No ill effect is produced by very high iron. The reason that agitation slightly lowers the voltage on the zero iron line is probably that the small quantities of sulphur dioxide present in the solutions have a slight depolarizing effect.

The relative values of sulphur dioxide and ferrous sulphate as depolarizing agents are taken up in Fig. 14. A solution showing but the merest trace of iron present by analysis was examined with varying proportions of sulphur dioxide added. Then sufficient ferrous sulphate was added to make the iron content 1.35 per cent. At 90 deg. Fahr. (32 deg. C.) and 13.2 amp. per square foot (145 per square meter), and in the absence of either ferrous iron or sulphur dioxide a voltage of nearly 1.9 is observed. Agitation drops this slightly, to about 1.8 volts. Adding SO_2 up to a content of 0.35 per cent has but little effect in the absence of agitation, but when agitated the cell voltage drops steadily as the strength of SO_2 increases; 0.35 per cent, however, brings the voltage down to but 1.25, and apparently a high content would be necessary to effect anything like the depolarization corresponding to the complete utilization of the anode oxygen. On the other hand, the moment any ferrous sulphate is added, the voltage drops to the value expected. It was, therefore, concluded that the presence in the liquor of the small quantities of sulphur dioxide which it is possible to absorb from relatively weak roaster gases, afforded no gain in depolarizing, while introducing various handicaps in other directions, so that ferrous sulphate was settled upon as the depolarizing agent and a minimum of 1.5 per cent ferrous iron determined upon.

Cathodes and Corrosion

Two problems were encountered at the cathode. The corrosive effect of the ferric sulphate produced at the anode made it difficult to obtain a high current efficiency, and under certain conditions the deposit would be tarnished by a film of copper sulphide.

The first difficulty is expressed by the reaction

$$Cu + Fe_2(SO_4)_3 = CuSO_4 + 2FeSO_4$$

Fig. 15 shows the corrosion rate to be expected in an acid solution of ferric sulphate. It is self-evident that the corrosion may be expressed in terms of weight lost per unit of superficial area of copper exposed to the wash of the liquor. It will be noted that the speed of the reaction is proportioned to the concentration of ferric iron and is greatly accelerated by heat.

The rates of corrosion were measured in a motor-

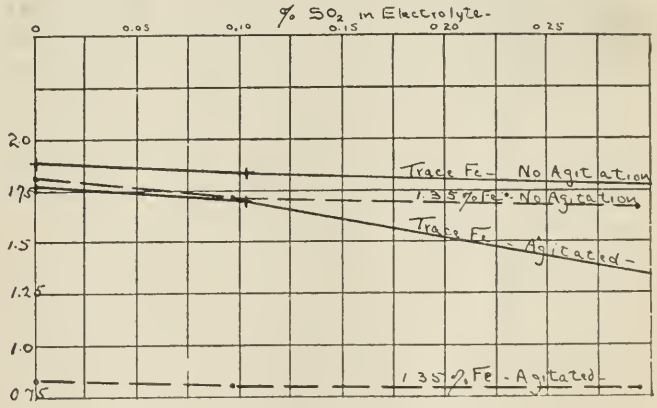


FIG. 14—VOLTAGE VS. SULPHUR DIOXIDE

2.6 per cent Cu, 4.3 per cent Al_2O_3, 4.2 per cent H_2SO_4, 90 deg. Fahr., 13.2 amp. per square foot (145 per square meter).

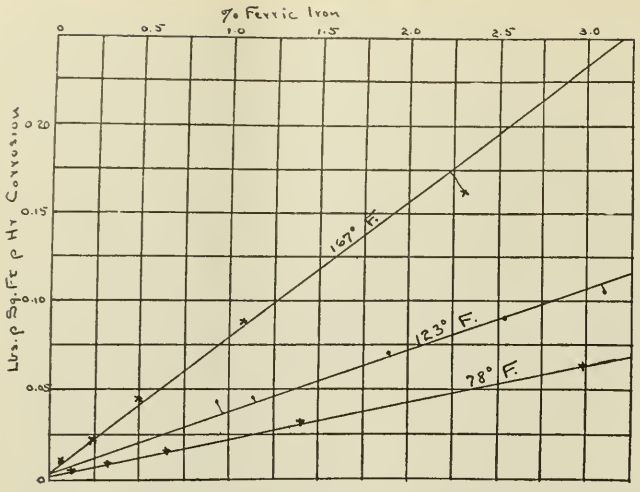


FIG. 15—REDUCTION OF FERRIC SULPHATE BY COPPER

Liquor: 4 per cent H_2SO_4 + × $Fe_2(SO_4)_3$.

driven shaking machine. This same apparatus was also used in the determination of the ferric iron in liquors. When simply a rate of corrosion was desired, the liquor was taken in such quantity that a measurable loss in the weight of the copper strip was obtainable without serious change to the strength of the liquor. When the ferric iron contents of the liquor was to be determined, on the other hand, the quantity of liquor was chosen so that complete exhaustion would not take an unreasonable time. Fig. 16 gives the characteristics of the machine. The oxidation error shown by constant loss in weight of the strip after twenty hours is very small.

The corrosion rates shown in Fig. 15 are very large. Thirteen amperes per square foot (143 per sq. m.) would deposit 0.034 lb. on a square foot (169 gr. per sq. m.) in an hour. From the diagram it appears that about 0.75 per cent ferric iron at 123 deg. Fahr. (51 deg. C.) would corrode as fast as the current deposited. A study was, therefore, made of the possible effects of the other components in the solution with quite remarkable results.

Fig. 17 shows the effect upon corrosion by adding either cupric, ferrous or aluminium sulphate to a liquor carrying 0.2 per cent iron as ferric sulphate and 4 per cent sulphuric acid. The copper and iron have but a slightly depressant effect upon the speed of reaction of the ferric iron upon the copper strip; the alumina, however, has a most marked effect and when the solution is practically saturated with aluminium sulphate the corrosion is almost completely arrested. Fig. 18 shows this same relation for a liquor carrying 3 per cent of both cupric and ferrous sulphates, being within the range of composition of a practical electrolyte. Fig. 19 shows that the amount of free acid present has but very slight effect. It, therefore, was determined to use aluminium sulphate as an antidote to ferric sulphate and it is believed this property of alumina may have wide application. No explanation is offered of the mechanism of this effect. It seems to slow down various reactions; for example, copper appears to cement upon iron with more difficulty. With alumina present, it is more difficult to depolarize, less sulphur dioxide can be absorbed, etc.

The second general difficulty, that of obtaining a bright deposit, was found to be due to the operation of several side reactions depositing either cupric sulphide or cuprous chloride upon the cathode. In the first place the work was done where the climatic conditions caused a tremendous amount of evaporation—some 200 units of water per unit of copper deposited had to be replaced—and the local water was full of salts, mainly chlorides. The electrolyte, therefore, rapidly built up in chlorides

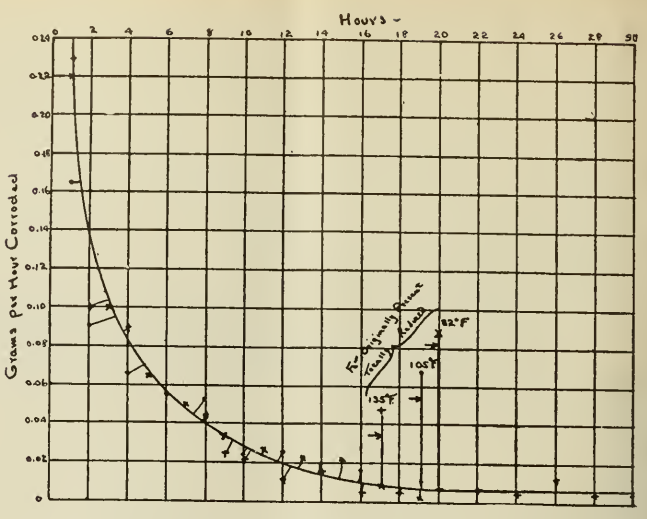


FIG. 16—OXIDATION ERROR OF SHAKING MACHINE

Liquor: 3 per cent Cu, 3 per cent Al_2O_3, 4 per cent H_2SO_4, 2 per cent Fe″, 1.4 per cent Fe‴. Copper strip 2½ sq. in. surface.

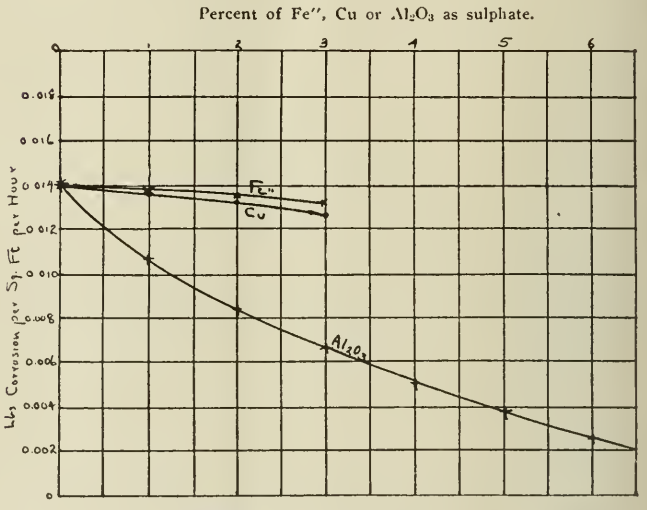


FIG. 17—RELATIVE EFFECTS OF COPPER, IRON AND ALUMINA ON CORROSION

Liquor: 4 per cent H_2SO_4, 0.2 per cent Fe‴, 105 deg. Fahr. (41 deg. C.).

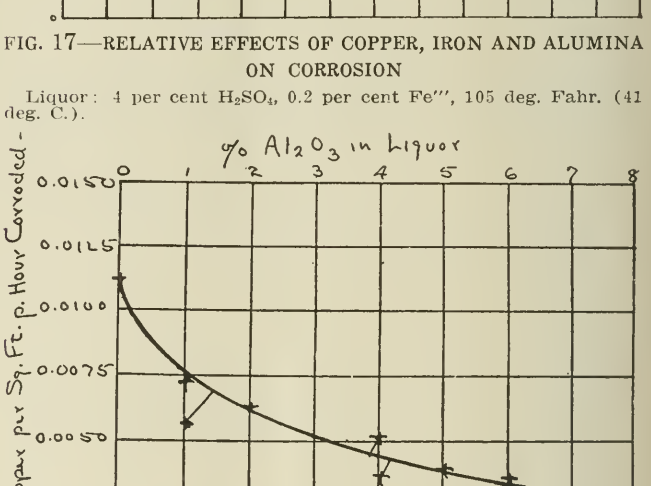


FIG. 18—EFFECT OF ALUMINIUM SULPHATE ON CORROSION

Liquor: 3 per cent Cu, 3 per cent Fe″, 0.2 per cent Fe‴, 4 per cent H_2SO_4, 105 deg. Fahr. (41 deg. C.).

until about 0.1 per cent Cl was found to be present by analysis. This resulted in a precipitation of cuprous chloride on the cathode which, owing to its actinic property, caused a tendency to blacken upon exposure to the light. Chlorine further reacted with the SO_2 when it was present in the liquors to form a cupric sulphide

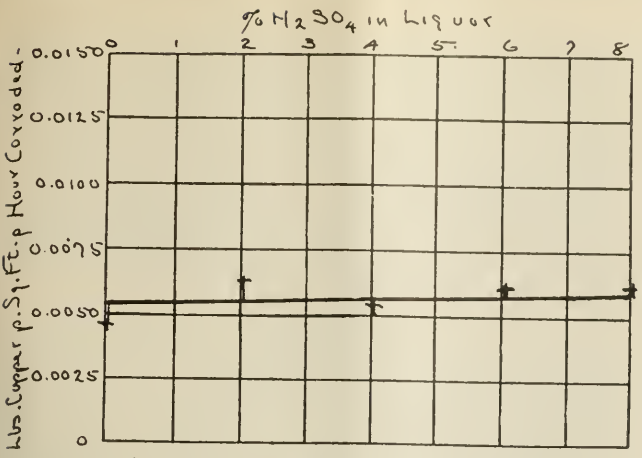


FIG. 19—EFFECT OF FREE ACID ON CORROSION

Liquor: 3 per cent Cu, 3 per cent Fe", 0.2 per cent Fe''', 3 per cent Al_2O_3; 105 deg. Fahr. (41 deg. C.).

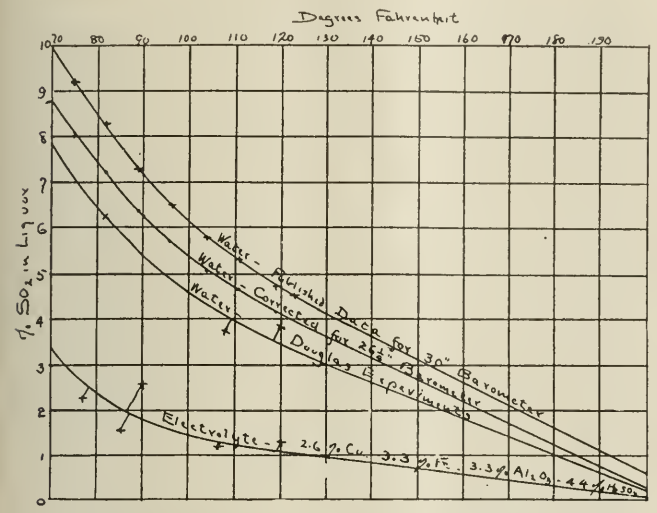

Degrees Fahrenheit
% SO_2 in Liquor
Water - Calculated Data for 30" Barometer
Water - Corrected for 26.25 in. Barometer
Water - Douglas Experiments
Electrolyte - 2.6 % Cu 3.3 % Fe 3.3 % Al_2O_3 4.4 % H_2SO_4

FIG. 20—SOLUBILITY OF SULPHUR DIOXIDE

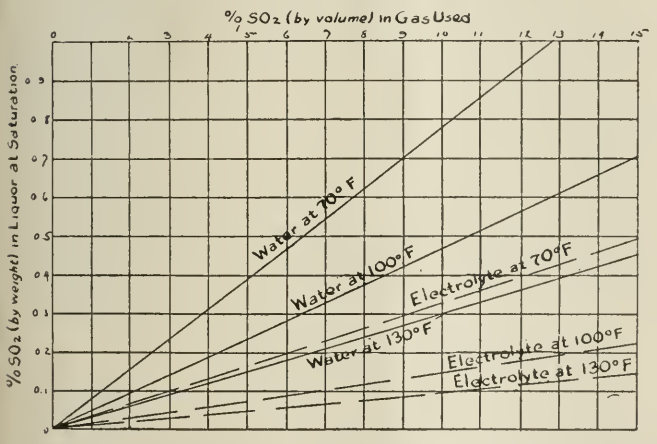

% SO_2 (by volume) in Gas Used
% SO_2 (by weight) in Liquor at Saturation
Water at 70° F
Water at 100° F
Water at 130° F
Electrolyte at 70° F
Electrolyte at 100° F
Electrolyte at 130° F

FIG. 21—APPLICATION OF HENRY'S LAW OF PARTIAL PRESSURES TO FIG. 20

film on copper. Finally unless the reduction of ferric sulphate by sulphur dioxide was carried out under proper conditions, some unknown practical products of reduction were formed which appeared to reduce to cupric sulphide at the cathode.

A brilliant deposit can easily be obtained where the liquor in the cells is free from chlorides or sulphur dioxide and any previous reduction of ferric sulphate has been properly carried out.

Sulphur Dioxide and Reduction of Ferric Sulphate

In Fig. 20 is given some data regarding the solubility of sulphur dioxide. In common with other gases its

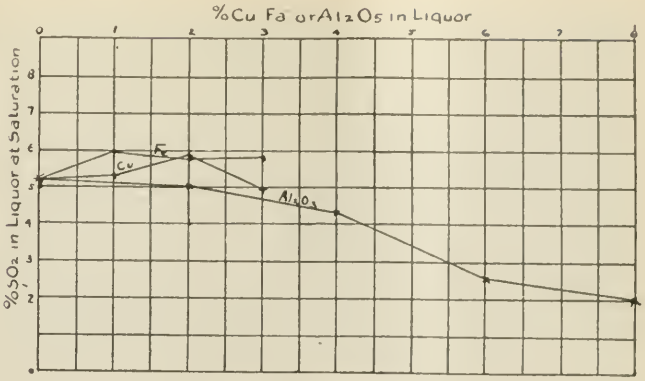


FIG. 22—EFFECT OF VARIOUS SULPHATES UPON SOLUBILITY OF SO_2

Liquor: 4 per cent H_2SO_4, 0.2 per cent Fe"; 70 deg. Fahr. (21 deg. C.).

solubility varies directly with the pressure and diminishes with increase of temperature until practically none remains in solution at the boiling point of the solvent. The curves in Fig. 20 are all for pure SO_2 gas at atmospheric pressure. The top curve is plotted from data in the published handbooks for the solubility of 100 per cent SO_2 in water at various temperatures at sea level and the next one corrects these data to the 26.25 in. (668 mm.) barometer under which the local experiments were made. The next lower curve shows the results obtained by simply bubbling gas through water until no further increase in dissolved SO_2 could be found by titration with iodine. The bottom curve gives the results of similar work using electrolyte as the solvent and a great decrease in the amount of SO_2 which can be absorbed will be noted. Of course, if the gas used runs less than 100 per cent SO_2, a corresponding diminution of the absorption value will be noted and Fig. 21 is a rearrangement of some of the data in Fig. 20, which shows just what can be expected with various strengths of roaster gas.

Figs. 22 and 23 are examples from a complete set of tests made, showing the effect of copper, iron and aluminium sulphates and free acid upon the solvent power of the liquor. It will be noted that the first two have but little effect, while the last two diminish markedly the amount of gas which can be dissolved. Supposedly 100 per cent gas was used in these tests. Fig. 24 shows the actual absorption obtained in practice, using a roaster gas in a tower some 6 ft. (1.8 m.) in diameter and 25 ft. (7.5 m.) high, packed with coke. In general it will be seen that we cannot hope to get more than a maximum of 0.2 per cent free SO_2 by analysis in electrolyte under operating conditions, unless compression of the roaster gas is resorted to. The furnace used was an ordinary six-hearth, 18-ft. (5.4 m.) MacDougall, arranged for metallurgical work, sending gases to waste so that 6 per cent SO_2 by volume was the maximum richness of gas obtainable.

We have three available reducing agents for ferric sulphate—sulphur dioxide, cement copper and the calcines leached as a source of copper.

For complete reduction, about 0.5 unit of sulphur as SO_2 is required for each unit of copper deposited, the iron sulphate acting as a carrier of oxygen from the anode to the SO_2 tower. As copper-bearing sulphide minerals generally carry about 2 units of sulphur per unit of copper, we have a margin of 75 per cent of the sulphur contents to cover losses in calcines, escaping tower gases and free SO_2 absorbed but later blown out of the liquors. The 0.5 unit utilized will add approximately 1.5 units free sulphuric acid to the system, which represents the amount of acid which would have to be

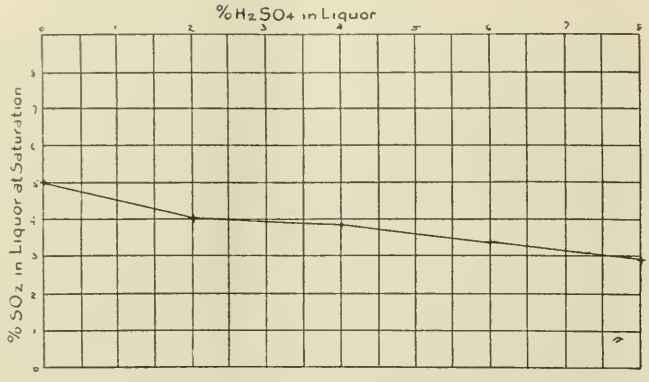


FIG. 23—EFFECT OF FREE ACID UPON SOLUBILITY OF SO_2

Liquor: 0.2 per cent Fe", 3 per cent Cu, 3 per cent Fe", 3 per cent Al_2O_3, 62 deg. Fahr. (17 deg. C.).

run away in purifying the electrolyte were SO_2 the sole source of reduction utilized.

There are several difficulties involved in the use of sulphur dioxide as a reducing agent, aside from the impossibility of obtaining a concentration stronger than 0.15 to 0.20 per cent in the liquors. When an acidified solution of ferrous sulphate is made up, it is a very pale green in color. Copper sulphate added to this at once masks this green entirely and the liquor appears a true blue. When this liquor is oxidized by anodic oxygen or by hydrogen peroxide, for example, the ferric sulphate formed turns it a bluish green. Now when SO_2 is bubbled through, it would be expected that the original blue would be restored, but unless the liquor is quite warm this is not the case, and if the liquor is hot the amount of gas absorbed is so small that but a small amount of reduction will exhaust its power. In a cool liquor the SO_2 turns the liquor a brilliant grass green, and it requires either heating to about 160 deg. Fahr. (71 deg. C.) or a period of rest of some sixteen hours to restore the blue color indicative of complete reduction. Neither of these methods are commercially practicable and the way of escape appears to be to use warm liquors, circulating them through the cells at such a rate that but about 0.1 per cent Fe is oxidized in transit, which small quantity a very small amount of free SO_2 seems capable of quickly reducing.

The next step is to use a certain proportion of cement copper as a reducing agent after the liquor leaves the tower. This not only readily reduces any traces of ferric iron or partial reduction compounds remaining, but precipitates any chlorides as cuprous chloride as

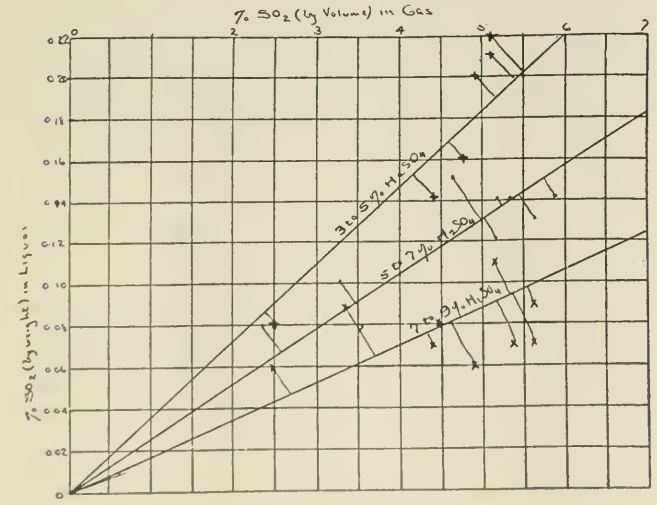


FIG. 24—SO_2 ABSORBED FROM ROASTER GAS IN PRACTICE

Liquor about 3 per cent Cu, 2.5 per cent Fe", 0.3 per cent Fe''', 3.7 per cent Al_2O_3, 85 deg. Fahr. (29 deg. C.).

well. Whatever iron, alumina or other impurities are dissolved from the calcines in leaching will have to be removed by systematic withdrawals of electrolyte which can be cemented upon iron. Perhaps 15 per cent of the copper leached will pass through this channel, and the method proposed forms an easy way of converting it to cathode copper.

The calcines to be leached are a fairly effective reducing agent for ferric sulphate, and at least half of the ferric iron contents of a liquor are reduced when passed through the leaching plant.

Efficiencies

We are interested in four efficiencies:

(1) *Current efficiency of cathodes.*
(2) *Quality of cathode.*
(3) *Efficiency of oxidation at anode.*
(4) *Sulphur efficiency.*

CURRENT EFFICIENCY AT CATHODE

About fifty separate runs were made in the cells shown in Fig. 2, during which some 4 tons of cathodes were deposited. The anodes shown in Fig. 5 were held rigidly in place on the cells, eight anodes and seven pairs of cathodes being used in each cell. In most of the work the liquor was circulated through four cells in series. The cathodes shown in Fig. 25 were freely suspended from their supporting bars by hooks made from insulated wire, but spacing blocks were so arranged that when the cathodes rocked under the influence of the compressed air agitation employed, they could not touch the anodes and cause short circuits. As mechanical short circuits were supposedly impossible, and as the agitation resulted in a beautifully smooth deposit without any tendency to form trees, we will assume that any deficiency from 100 per cent efficiency at the cathode was due to redissolving of the copper by ferric sulphate formed at the anode.

We have six factors influencing the rate of corrosion at the cathode; the concentration of ferric sulphate in the electrolyte, the temperature of the electrolyte, the concentration of aluminum sulphate in the electrolyte, the efficiency of contact with the cathode due to agitation, the surface exposed to corrosion and the offsetting effect of the rate of deposit, or, in other words, current density.

The influence of the first of these factors, the concentration of ferric sulphate, under operating conditions, is shown in Fig. 27, where the average of the ferric sulphate entering and leaving the cells in the large scale runs is plotted against the current efficiency obtained. The existence of other variables scatters the points more or less, but the relationship is clearly indicated.

The temperature of the electrolyte was held at about 120 deg. Fahr. (40 deg. C.) entering the cells in most of the large scale runs. In the presence of aluminum sulphate the effect of temperature upon corrosion is not very marked.

The aluminium sulphate was consistently held above 3 per cent and in general the protective relationship established in the small tests was verified.

The rate of agitation employed was determined entirely by the voltmeter readings. The higher the alumina the greater the agitation called for and a limit around 4 per cent Al_2O_3 was reached where the cells foamed badly.

The surface exposed to corrosion enters in rather an unexpected way. As long as the current efficiency is 65 per cent or over, the corrosion seems quite uniform and the cathode remains relatively smooth. Below this efficiency, however, the corrosion cuts grooves or furrows in the cathodes. These furrows present increased

surface to corrosion and an unstable condition ensues which causes the efficiency to fall day by day until a very low value is reached. The difference in appearance between cathodes which have been operating above and below this critical value is shown in Figs. 25 and 26.

The current density in the large scale runs was held at 13 amp. per square foot (143 per square meter) because it was found difficult to obtain thorough depolarization at higher rates.

QUALITY OF CATHODE

Physically, most beautiful cathodes were made when the rate of corrosion was properly controlled. This was, of course, due to the burnishing effect of the agitation in the cells. Chemically, three possibilities have to be considered—fouling by cuprous chloride, contamination by copper sulphide and plating out of arsenic, etc.

Cuprous chloride is purely a local problem where the water supply or the calcines carry chlorides and the use of cement copper appears to be an adequate remedy. Some cathodes made without the use of cement, analyzed 2.9 per cent Cl, while others made where cement was used showed 0.4 per cent Cl, indicating that a more thorough use of the cement would eliminate the cuprous chloride without difficulty. This same problem is being handled at Chuquicamata by precipitating upon shot copper.

The proper reduction of ferric sulphate by sulphur dioxide will not leave partial compounds which blacken the cathodes. While some of the earlier copper showed the presence of sulphur, the later runs gave out 0.002 to 0.003 per cent.

Small scale experiments, using an electrolyte to which 1 per cent arsenic as As_2O_3 had been added, yielded cathodes running but 0.0011 per cent As.

ANODE EFFICIENCY

The anode efficiency was ascertained for twenty-seven of the large-scale runs, as follows:

The theoretical oxidation of ferrous sulphate was calculated from the cell—ampere—hours for each run. The gain in ferric sulphate was then figured from the quantity of liquor circulated and the shaking machine determinations on the entering and leaving liquors. To this was added the quantity of ferric iron reduced at the cathode as shown by the current efficiency, the sum being the iron actually oxidized electrolytically at the anode and chemically by the air used in agitation. The results ran in general from 90 to 115 per cent. Some runs, to determine the amount of oxidation due to the air, indicated perhaps 15 per cent, so that the depolarization was apparently perfect.

SULPHUR EFFICIENCY

We have available, in general, 2 units of sulphur per unit of copper. We lose perhaps 10 per cent in the calcines and some, let us say another 10 per cent, must be lost in the exhausted tower gases. We have an anode efficiency of oxidation of say 110 per cent, including that due to the agitation. This will call for 0.55 unit sulphur per unit of copper, in the form of SO_2, to reduce the equivalent ferric sulphate. We have, therefore:

Lost in calcines	0.20 unit
Lost in tower gases	0.20 unit
Used in reduction	0.55 unit
	0.95 unit
Total available	2.00 unit
Possible loss in liquor	1.05 unit S per unit Cu.

If we assume 0.15 per cent free SO_2 in liquor leaving the tower, this 1.05 units will supply 700 units of liquor. We must, therefore, remove 1 unit of copper by deposition from 700 units, or less, of liquor. This corresponds to an oxidation of 1.77 units of iron, or 0.25 per cent increase in ferric iron in passing through the cells. This comes within the danger limit shown by Fig. 27. If we wish to run at lower ferric iron increase we must recover some of the free excess SO_2 in the liquor and use it again in a secondary tower, or figure on less than 0.15 per cent in the liquor leaving the tower.

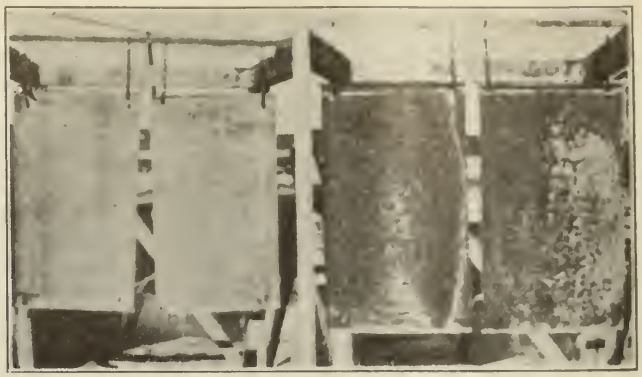


FIG. 25—SMOOTH CATHODES FIG. 26—FURROWED CATHODES

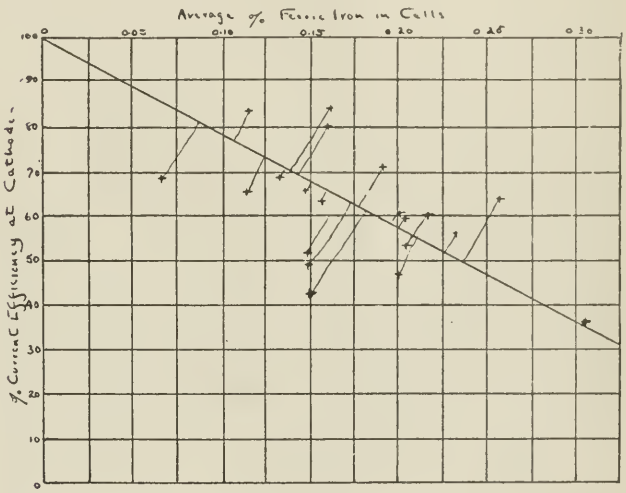


FIG. 27—EFFECT OF FERRIC SULPHATE UPON CURRENT EFFICIENCY IN PRACTICE

Liquor about 5 per cent H_2SO_4, 3 per cent Cu, 2.5 per cent Fe", 3.7 per cent Al_2O_3, 118 deg. Fahr. (48 deg. C.).

CONCLUSIONS

Carbon anodes will stand up in sulphate liquors if they are properly depolarized.

Aluminium sulphate can be used as a substitute for a diaphragm.

2.25 lb. (1.019 kg.) of copper per kilowatt-hour can be recovered under proper operating conditions.

Great quantities of various sulphates present as impurities do not foul the cathodes.

Three or possibly 3.25 units of acid are made per unit of copper, of which 1.5 to 1.75 units are new acid from the tower gases.

No mechanical difficulties are experienced in the tower, but a thorough study remains to be made of the chemistry of reduction of ferric sulphate by sulphur dioxide in order to utilize the roaster gas to best advantage.

The New Jersey iron mines in Morris County are reported to be very active, foremost among these being the Empire Steel & Iron Co. at Mount Hope and the Thomas Iron Co. at Richard Mine. The former is shipping about 17,000 tons of ore per month and the latter 6000 tons.

Recent Advances in the Manufacture of Cyanogen Compounds*

BY J. E. CLENNELL

Fixation of Atmospheric Nitrogen

Much activity has been shown of late in the study of methods for the fixation of atmospheric nitrogen, and a number of products are now made on a large scale both for direct use and as a basis for the production of other nitrogenous substances. The most remarkable development has been in the manufacture of calcium cyanamide, $CaCN_2$. Impure commercial products consisting mainly of this substance are now extensively used as fertilizers under the names of "lime nitrogen" and "nitroline." Alkali cyanides and other cyanogen compounds are obtained by further treatment of cyanamides in a variety of ways. Other processes are used to transform cyanamide into ammonia, ammonium salts and other nitrogenous compounds of commercial value.

The earlier attempts at the fixation of atmospheric nitrogen were mostly based on the reactions taking place between barium oxide, carbon and nitrogen at high temperatures. An important investigation of this process has been published by Thomas Ewan and Thomas Napier,[1] who summarize the chief data obtained by previous investigators in this field. The formation of cyanides from a mixture of BaO, C and N requires a minimum temperature of 1200 deg. C., but proceeds best at 1400 deg. C., when 40 per cent of the Ba may be cyanized. Hempel (1890) showed that the percentage of Ba cyanized may be increased by pressure. Readman (1894) applied the electric furnace for this process, which has been carried out on a large scale by the Scottish Cyanide Company. Frank and Caro showed (1898) that a large part of the nitrogen is fixed in the form of barium cyanamide, $BaCN_2$. Caro also found (1907), that the addition of alkali and alkaline earth fluorides accelerates the reaction, and enables it to proceed at temperatures of 900 deg. to 1100 deg. C. Snodgrass (1907) showed that potassium carbonate has a similar action.

Ewan and Napier (1909) studied the action of catalysts to obtain the reaction at lower temperatures. In their first experiments, mixtures of barium carbonate and charcoal were placed in an iron boat in a porcelain tube, and heated in a current of dry nitrogen. The products finally obtained were barium cyanide $Ba(CN)_2$, barium cyanamide $BaCN_2$, carbon monoxide CO, and unaltered $BaCO_3$, C and N. The following reactions are supposed to occur:

$$BaO + 2C + N_2 \rightleftarrows BaCN_2 + CO$$
$$BaO + 3C + N_2 \rightleftarrows Ba(CN)_2 + CO$$

They summarize their results as follows:

1. Absorption of nitrogen begins at 900 deg. to 930 deg. C.

2. The amount absorbed increases rapidly from 1 per cent Ba combined at 930 deg. to 40 per cent at 1000 deg., in tests made under the conditions that four molecules of N act on one molecule of $BaCO_3$ for a period of two hours.

3. The greater part of the nitrogen is fixed as cyanide $Ba(CN)_2$ and not as cyanamide. When calcium is used in place of barium, the nitrogen is fixed almost exclusively as cyanamide, $CaCN_2$.

4. At 960 deg. about 2½ per cent of the nitrogen is fixed; at 1000 deg. about 10 per cent.

5. Addition of K_2CO_3 seems to improve the result, but the difference obtained falls within the limits of error in estimating temperatures.

6. No cyanide is produced until about 30 per cent of the $BaCO_3$ is converted into BaO, and until the percentage of CO has fallen to 30.

It is commonly supposed that barium carbide (BaC_2) is formed as an intermediate product, but Ewan and Napier find no evidence of this. From theoretical considerations BaC_2 could not be formed at all in presence of mixtures of CO and N from which N is freely absorbed by BaO and C. It is probable, however, that when calcium is used instead of barium the reaction:

$$CaC_2 + CO \rightleftarrows CaO + 3C$$

is a necessary intermediary.

Cyanid Gesellschaft[2] reports that nitrogen has no action on a mixture of CaO and C at 1100 deg., and that the reaction $CaO + 2C + N_2 = CaCN_2 + CO$ takes place best at 2000 deg. At this temperature nearly all the nitrogen is absorbed.

K. Kaiser[3] observes that if barium oxide or carbonate, intimately mixed with carbon, be heated to 900 deg. to 1400 deg. C. and allowed to cool in a dry atmosphere of nitrogen under pressure, as much as 90 to 95 per cent of the theoretical amount of nitrogen combines with the barium.

A French patent[4] of 1913 describes a method of carrying out the reaction between barium carbonate, carbon and nitrogen in an electric furnace. Tar is used as binding material for the ingredients; these are molded into balls and part of the bar recovered by distillation. The residue is then heated to 1600 deg. C. in the electric furnace and acted on by "producer gas" or other gas containing nitrogen, to form barium cyanide. The electrodes consist of two rings of carbon placed at the ends of the middle reaction zone of an inclined cylindrical furnace; the fused mass serves to conduct the current. Barium oxide may be regenerated by decomposing the barium cyanide by means of steam:

$$Ba(CN)_2 + 3H_2O = BaO + 2NH_3 + 2CO$$

When calcium is used instead of barium as the vehicle for the fixation of nitrogen, it was found by Barzano and Zanardo[5] that the yield of calcium cyanamide is increased by mixing calcium carbide with sufficient calcium cyanamide from a previous operation to form a friable mass, before subjecting it to the action of nitrogen.

The manufacture of cyanamide by the process of Frank and Caro is carried out on a large scale at the works of the American Cyanamide Company, Niagara Falls, Ontario.[6] Nitrogen is obtained by passing air over heated copper. The copper oxide thus formed is again reduced by the action of natural gas, so that it may be used repeatedly. Operations began in January, 1910, with a 10,000-ton plant, which has since been largely extended.

Cyanides and cyanamides of the alkali metals may be produced without the preliminary formation of a calcium or barium compound. E. A. Ashcroft[7] proposes to do this by using an alloy of the alkali metal with some heavy metal such as lead, and first fusing this with a portion of the product sought (e. g., NaCN or Na_2CN_2) at about 600 deg. C., to separate the alkali from the heavy metal. The resulting melt, freed from the heavy metal, is now caused to react with cyanogen or a substance yielding cyanogen, with or without electrolysis of the melt.

*The second part of a paper entitled "Recent Advances in the Chemistry of the Cyanogen Compounds," to be presented at the New York City meeting (February, 1916) of the American Institute of Mining Engineers. The first part of the paper deals with advances in the chemistry of ore treatment by cyanide.

[1]Journal Soc. Chem. Ind., vol. 32, p. 467 (May 15, 1913).

[2]English Patent 16,298, 1902.

[3]French Patents 454,237 and 454,238, Feb. 11, 1913.

[4]F. Gros, P. Goissedet, F. Bouchardy and M. Fossier. French Patent 460,684, July 23, 1913.

[5]French Patent 456,826.

[6]Metall. & Chem. Eng'ing, vol. 12, p. 265 and vol. 13, p. 213.

[7]English Patent 1002, Jan. 12, 1912.

Conversion of Cyanamides Into Cyanides, Etc.

We must now mention some of the recently proposed methods for converting calcium cyanamide into cyanides or other nitrogenous substances of commercial value. These may be roughly classified as fusion methods and wet methods.

Among the former, probably the best known is that of Erlwein and Frank[8] by which the crude calcium cyanamide is converted into a product containing the equivalent of 25 to 30 per cent KCN, by fusing with carbon and common salt. Careful regulation of the temperature appears to be necessary. I have found that the process is not easily imitated in laboratory experiments. The product has been placed on the market under the name of "surrogat." For extraction of precious metals, it appears to be as effective, per unit of cyanogen contained, as ordinary sodium cyanide. It requires, however, to be digested with water and the insoluble carbonaceous residue filtered off before use.

J. C. Clancy[9] proposes to heat calcium cyanamide with its own weight of a mixture of equal parts of sodium sulphide and chloride in presence of carbonaceous matter.

E. E. Naef[10] treats crude calcium cyanamide at a temperature of 300 to 500 deg. C. with sulphur or a substance yielding sulphur:

$$2CaCN_2 + S = CaS + Ca(CN)_2 + N_2$$

The product is then stirred with water and filtered from the residue of $CaS + C$. The filtrate is boiled gently with zinc dust, and the zinc cyanide formed converted into alkali cyanide by known methods.

Calcium cyanamide may be used as a source of ammonia by acting on it with steam under pressure at a temperature of 170 deg. C., using an agitator to prevent formation of lumps. C. Manuelli[11] observes that under favorable conditions nearly theoretical yields of ammonia can be obtained at a cost of about 1.7 cents per pound of nitrogen utilized. Another method (E. E. Naef)[12] is to pass a current of dry hydrogen, either alone or mixed with CO_2, CO or N, at ordinary or higher pressure, over a heated mass of calcium cyanamide.

The wet methods are based on the fact that cyanamide compounds, such as $CaCN_2$, are transformed by water into the sparingly soluble crystallizable salt dicyandiamide $(CN{\cdot}NH_2)_2$. At a temperature of 13 to 14 deg. C. about 90 per cent of the nitrogen of calcium cyanamide may be dissolved in twenty-five times its weight of water, in eight hours, the extraction proceeding rapidly at first but very slowly later (C. Manuelli)[11]. Various salts of dicyandiamide may be prepared by digesting the substance in presence of acids with the oxides of the metals whose salts are required. The polymerization of cyanamide in aqueous solution is promoted by addition of fixed alkalis or ammonia. According to Grube and Krüger,[13] the reaction appears to be due to the union of undissociated cyanamide $(CN{\cdot}NH_2)$ with cyanamide ions $(CN{\cdot}NH)'$, to form monobasic dicyandiamide ions $H{\cdot}(CNNH)'_2$, presumably in the following stages:

(*a*) Formation of cyanamide by hydrolysis of calcium cyanamide:

$$CaCN_2 + 2H_2O = Ca(OH)_2 + CN{\cdot}NH_2$$

(*b*) Dissociation of a part of the cyanamide:

$$CN{\cdot}NH_2 = H' + (NC{\cdot}NH)'$$

(*c*) Combination of dissociated with undissociated cyanamide:

$$(CN{\cdot}NH)' + CN{\cdot}NH_2 = H(CN{\cdot}NH)'_2$$

(*d*) Formation of dicyandiamide:

$$H(CN{\cdot}NH')_2 + H' = (CN{\cdot}NH_2)_2$$

It is found that at a given concentration of total cyanamide, polymerization proceeds most rapidly when the concentrations of cyanamide and of dissociated cyanamide ions are equal.

For the preparation of dicyandiamide from commercial calcium cyanamide, the addition of a foreign base is unnecessary; the conversion may be brought about by precipitating the lime at intervals so as to maintain approximately equal concentrations of $CN{\cdot}NH_2$ and $(CNNH)'$.

Alkali salts of dicyandiamide are produced by heating the substance with caustic alkalis in presence of an absorbent of water:[14]

$$4NaOH + (CNNH_2)_2 = (CN{\cdot}NNa_2)_2 + 4H_2O$$

If the water is not absorbed, part of it reacts with the melt thus:

$$Na_2CN_2 + 3H_2O = Na_2CO_3 + 2NH_3$$

The absorbents used are alkali or alkaline earth metals or their oxides, amides, nitrides, carbides or alloys.

Dicyandiamide is converted into cyanide by fusing with alkaline carbonates and carbon

$$(CN{\cdot}NH_2)_2 + Na_2CO_3 + 2C = 2NaCN + NH_3 + N + H + 3CO$$

or it may be converted into a variety of nitrogenous products suitable for manures, explosives, etc.

The conversion of cyanamide into dicyandiamide may also be brought about by heating its solution with a catalytic agent. H. Immendorf and H. Kappen[15] propose to carry out this process by means of ferric oxide on hydrate, manganous or manganic oxides or their hydrates, stannic acid, chromic oxide or hydrate, hydrated silicic acid or similar substances. The products obtained are ammonia, urea and dicyandiamide. During the process the catalyst absorbs the bases liberated and loses its efficiency. This may be restored by treatment with acid or with water. Commercial calcium cyanamide contains calcium chloride, which hinders the separation of urea and dicyandiamide. This difficulty may be avoided by converting the calcium chloride into sulphate or carbonate, which may be separated by reason of their insolubility in alcohol.

H. Kappen[16] obtains thiourea by treating dilute aqueous solutions of cyanamide with hydrogen sulphide at high temperatures, in closed vessels under pressure. The addition of acid and alkaline reagents and of soluble compounds of arsenic, antimony or tin increases the efficiency of the process.

Production of Cyanogen Compounds from Nitrogenous Gases by Catalysis and Otherwise

Another method for the manufacture of cyanides and related compounds, which has been largely developed of late years, consists in the contamination, under suitable conditions, of volatile carbon and nitrogen compounds. Usually this takes place at a high temperature under the influence of a "catalyst," *i.e.*, of some substance which does not undergo any permanent chemical change in the process.

It has long been known that hydrocyanic acid or ammonium cyanide could be produced by passing mixtures of carboniferous and nitrogenous gases over heated platinized pumice, as for example in Wolterech's process:[17]

$$CO + NH_3 = HCN + H_2O$$

C. Beindl[18] proposes to form hydrocyanic acid and

[8]U. S. Patent 708,333.
[9]U. S. Patent 1,112,893, Oct. 6, 1914. Assigned to Portland Mining Co.
[10]English Patent 14,607, June 22, 1912.
[11]Annali Chim Appl. 1914, 1, p. 388 and 412.
[12]English Patent 14,412, June 20, 1912.
[13]Zeit. f. Phys. Chem., vol. 86, p. 65. 1913.
[14]Chem. Fabr. von Heyden, A. G. German Patent 267,595. Feb. 2, 1913.
[15]German Patent 256,524, Dec. 25, 1910.
[16]German Patent 260,061, Nov. 1, 1911.
[17]English Patent 19,804, 1902.
[18]German Patent 254,068, Feb. 15, 1912.

cyanogen compounds by catalytic combination of gaseous and volatile carbon compounds with gaseous and volatile nitrogen compounds, by the use of a contact material consisting of a metallic oxide or a mixture of metallic oxides. The gaseous mixture should contain not more than 7 volumes of the carbon compound to 1 volume of the nitrogen compound. It is claimed that oxides of metals of the iron group have the property of inducing the rapid formation of hydrocyanic acid at relatively low temperatures, from dry mixtures of these gases.

It has been found[19] that the yield is increased by introducing into the arc of an electric furnace the vapors of metals and metallic compounds, such as those of copper or iron and their salts.

W. Moldenhauer and O. Wehrheim[20] describe a method by which nitric oxide can be obtained by catalytic combustion of cyanogen compounds. Ammonia may also be used as the source of nitrogen, but the yield of nitric oxide is less than with cyanogen, and more attention must be paid to the condition of the catalyst and time of contact with it.

J. E. Bucher[21] proposes to produce alkali cyanides by the action of atmospheric nitrogen on alkali carbonate and carbon dissolved in iron, the iron acting as a catalytic agent. The alkali cyanide formed is removed from the reaction zone by distillation under diminished pressure.

The Deutsche Gold und Silber Scheide Anstalt[22] propose to pass gaseous mixtures containing nitrogen obtained by heating certain waste products such as "vinasses" through highly heated conduits lined with refractory material such as Dinas brick, fused quartz, or a fused mixture of zirconia and quartz which remains gas-tight and non-porous at the high temperature employed. It is said that practically the whole of the nitrogen is obtained in the forms of HCN and NH_3, the relative proportions of these varying with the raw material used.

In the process of Barzano e Zanardo[23] a mixture of nitrogen (say 60 per cent), hydrogen (32 per cent) and hydrocarbons (6 per cent) is raised to a high temperature, for example in the electric arc, and hydrocyanic acid absorbed by circulating the issuing gases through cooling and absorption apparatus. Sufficient nitrogen is added to maintain, with the hydrogen liberated, the concentration of these gases most favorable to the reaction.

Catalysis may be employed for the production of ammonia, not only from gaseous mixtures but also from solid organic nitrogenous compounds. F. Schreiber[24] proposes to act on the latter with contact masses containing hydrated iron oxide at temperatures below red heat. It is claimed that as much as 80 per cent of the nitrogen in pyridine and in cyanogen salts may be thus converted into ammonia, while ordinary destructive distillation yields not more than 20 per cent.

Production of Cyanogen Compounds from Gaseous Mixtures by Absorption with a Metallic Salt

The cyanogen contained in crude illuminating gas has for some years been utilized as a source of cyanides and cyanogen compounds on a commercial scale, as in the methods of Rowland[25] and Bueb[26].

[19]Konsortium f. Elektrochemische Industrie, G. m. b. H. German Patent 268,277, July 1, 1911. Addition to German Patent 263,692.
[20]Zeit. f. Angewandte Chemie, vol. 27, p. 334, 1914.
[21]U. S. Patent 1,094,976. Assigned to Nitrogen Products Co.
[22]German Patent 255,440, Nov. 9, 1911. French Patent 448,772, Sept. 5, 1912.
[23]French Patent 456,826.
[24]German Patent 257,188, June 2, 1911.
[25]U. S. Patent 465,609, 1891.
[26]English Patent 9,075, 1898.

L. Bergfeld[27] uses as purifying material dehydrated copper sulphate, or a mixture of salts, *e.g.*, alkaline earth sulphates or chlorides, which combine with NH_3 but not with H_2S, with metallic oxides capable of combining with H_2S. The mixture is treated with ammonia gas before use. The reaction is of the type:

$$H_2S + NH_3 + CaSO_4 \cdot NH_3 = CaS + (NH_4)_2SO_4$$

At the same time some SO_2 (which is fixed by the purifying material) and sulphur are also formed, thus:

$$SO_3 + H_2S = H_2O + SO_2 + S$$

When the purifying material is extracted it is heated, with regulated access of air, and ammonia liberated.

By gentle warming in presence of air, the ammonium sulphite deposited is rapidly oxidized to sulphate.

Cyanogen in the crude gas is fixed by the purifying material as cuprous ammonium cyanide. On heating with air this yields NH_3 and CO_2, and thiocyanate giving NH_3, CO_2 and SO_2. After passing the purifying material the coal gas may be further purified by leading it over alkali or alkaline earth sulphides, and if necessary over sodium amalgam.

C. A. Bergh[28] uses a solution of a zinc salt, containing also ferrous chloride, as an absorbent. The free acid formed is neutralized, and zinc sulphide and cyanide are precipitated, by addition of calcium carbonate, or some other sparingly soluble substance. This is added in quantity corresponding to the amount of H_2S and CN present. Iron remains in solution. By this method zinc is separated from iron and H_2S from CN by a single operation.

W. H. Coleman[29] passes coke-oven or other gases containing hydrocyanic acid through a tower packed with lumps of ferrous iron ore. A solution of sodium carbonate, or other suitable alkaline absorbent in solution or suspension, is circulated through the tower, and the resulting alkali or alkaline-earth ferrocyanicide liquor is treated for recovery of the ferrocyanide.

Foreign Markets for American Chemicals*

BY DR. THOMAS H. NORTON
Bureau of Foreign and Domestic Commerce.
Department of Commerce

Never before in our industrial history has the American manufacturer sought with more energy to gain a foothold in foreign markets. Never before have the opportunities for success in this field been so marked.

A titanic struggle is slowly sapping the strength of the chief European rivals of our country. Their power to maintain successful and prolonged competition is steadily diminishing, day by day.

Two nations, Germany and Austria-Hungary, are practically shut off from international markets. The ability to manufacture in other European nations is seriously impaired through the lack of workmen, through the difficulty of securing raw materials, through the more or less serious dislocation of the whole machinery for effecting the world's exchanges.

In the midst of this uncertainty this disorganization which prevails to a greater or less degree in the various European centers of production, it is a patriotic duty of American branches of manufacture to strive by every honorable means in their power to gain a permanent foothold in markets of all countries, neutral or belligerent.

What are the American manufacturers of chemicals doing to win new customers for their wares?

[27]German Patent 255,593, Aug. 24, 1910.
[28]German Patent 272,904, March 19, 1912.
[29]English Patent 27,908, Dec. 4, 1912.
*A paper read at the meeting of the American Institute of Chemical Engineers held in connection with the First National Exposition of Chemical Industries in New York City on Sept. 22, 1915. Slightly abstracted.

In order to answer this question we must first establish the extent to which American chemicals were purchased in foreign countries prior to the great war. Next we can note the temporary effect of the war on our trade in chemicals. Finally, we should ascertain along what lines of least resistance an export trade in American chemicals can most easily and effectively be built.

AMERICAN EXPORTS OF CHEMICALS PRIOR TO THE WAR AND DURING THE WAR

Table I gives the principal items of export, during the fiscal year, ending June 30, 1914 and 1915; enumerated under the head of "Chemicals, Drugs, Dyes and Medicines" in the statistical reports of the Bureau of Foreign and Domestic Commerce:

TABLE I

Articles	1914		1915	
	Quantity	Value	Quantity	Value
Acids:				
Sulphuric, lb	12,131,750	125,892	46,771,510	516,436
All other	.....	357,035	.....	2,611,741
Alcohol, wood, gal	1,598,776	652,486	944,374	438,846
Baking powder, lb	2,725,964	750,274	3,376,780	881,879
Bark, extracts of, for tanning	.....	639,941	.....	2,226,457
Calcium carbide, lb	32,845,649	962,040	35,772,867	1,097,952
Copper, sulphate of, lb	7,375,775	330,007	10,238,808	445,580
Dyes and dyestuffs	.....	356,919	.....	1,177,925
Ginseng, lb	224,605	1,832,686	103,184	919,931
Lime, acetate of, lb	68,160,224	1,560,933	24,673,247	486,405
Medicines, patent or proprietary	.....	6,721,978	.....	7,130,379
Petroleum jelly, etc	.....	661,889	.....	838,842
Roots, herbs, and barks, crude, not mixed	.....	513,071	.....	470,090
Soda salts and preparations	.....	.....	.....	3,141,022
Sulphur or brimstone, crude, tons	110,022	2,018,724	48,391	885,756
Washing powder and fluid, lb	12,761,958	535,635	14,695,317	635,476
All other	.....	9,019,582	.....	22,476,269
Totals	.....	$27,079,092	.....	$46,380,986

The variations in trade are somewhat more sharply marked if comparison is made of the exports during the months of June, 1914 and 1915. This is illustrated by Table II.

TABLE II.—EXPORTS DURING THE MONTH OF JUNE

Articles	1914		1915	
	Quantity	Value	Quantity	Value
Acids:				
Sulphuric, lb	647,498	5,948	5,931,208	63,516
All other	.....	23,102	.....	354,591
Alcohol, wood, gal	165,463	62,769	58,508	30,108
Baking powder, lb	249,446	74,634	320,953	85,142
Bark, extracts of, for tanning	.....	69,834	.....	506,289
Calcium carbide, lb	1,996,632	57,978	3,251,754	92,633
Copper, sulphate of, lb	281,445	12,265	144,268	9,115
Dyes and dyestuffs	.....	40,380	.....	204,732
Ginseng, lb	31,680	244,145	9,088	77,033
Lime, acetate of, lb	6,908,360	112,743	2,589,641	73,950
Medicines, patent or proprietary	.....	521,309	.....	780,811
Petroleum jelly, etc	.....	50,094	.....	88,923
Roots, herbs, and barks, crude, not mixed	.....	39,057	.....	77,149
Soda, salts and preparations	.....	.....	.....	684,355
Sulphur or brimstone, crude, tons	9,342	173,125	1,637	35,088
Washing powder and fluid, lb	1,508,698	59,402	1,322,231	59,715
All other	.....	876,409	.....	3,114,756
Totals	.....	$2,423,203	.....	$6,337,906

It will be noticed that the fiscal year recently elapsed, has witnessed notable increases in amount exported for the following articles: Sulphuric and other acids, calcium carbide, dyes and dyestuffs, petroleum jelly and other articles.

Decreases are noted in the case of wood alcohol, copper sulphate, ginseng, calcium acetate, sulphur.

There is little variation in the amount exported of baking powder, medicines, roots and washing powder.

As a whole the export of chemicals for 1915 shows an advance in value of 72 per cent over that of 1914.

The export of June, 1915, is 161 per cent greater than that of 1914.

The classification of the Department of Commerce does not include explosives, which increased in value from $6,272,000 in 1914, to $41,476,000 in 1915. It does not include also the heavy exports of cement, ink, mineral oils, paints, pigments, and varnish, perfumery, soap and a few other items, closely allied to the chemical schedule, but in which the variations in the volume of export were not of material importance.

It is quite evident that apart from munitions, the war has brought about a very pronounced increase of our chemical exports both in volume and in value. It is unfortunately impossible at present to have the complete data now being collected so that we may gain an adequate idea of the geographical distribution of the increase in exports during the past year. It suffices for the moment to note that the existing international conditions have very distinctly favored the expansion of the foreign market for American chemicals.

MARKETS OPEN TO AMERICAN CHEMICALS

And now, how can we most effectively build up an export trade in chemicals?

Evidently the existence of a world-wide war presents peculiar opportunities which can be utilized with perfect freedom, in the firm conviction that no ethical law is violated. With the friendliest of feelings toward Briton and Teuton, and the allies of both, we recognize that each of these two countries, normally so prominent in the export of chemicals, is now unable to meet fully the normal demands upon its productive capacity. A strong effort, on the part of American manufacturers of chemicals, to fill these demands is undoubtedly dictated by the circumstances, and it is likewise our duty to aim to build up permanent trade relations in those fields. It is most deplorable and unfortunate, from the standpoint of humanity, that such intense bitterness is awakened by the great conflict across the water. For years it will influence currents of trade; on the advent of peace, entire nations will apparently refuse to purchase the products of certain other nations.

The existence of such a factor of hostility and antagonism between nations hitherto closely related in international trade, is most regrettable. We can but hope that it eventually will disappear. In the meantime without encouraging any act on our part, we are legitimately free to do our best to meet the demands which may be made upon every branch of our national industry, and presumably upon our chemical industry, to an extent hitherto unknown.

Let us note what chemical products of the leading

TABLE III.—IMPORT OF CHEMICALS INTO DIFFERENT COUNTRIES

EUROPE			
Austria-Hungary	$20,386,000	Portugal	$1,864,000
Belgium	28,814,000	Roumania	1,191,000
Bulgaria	718,000	Russia	16,081,000
Denmark	3,897,000	Finland	306,000
France	32,900,000	Servia	245,000
Germany	79,394,000	Spain	10,224,000
Greece	1,180,000	Sweden	4,005,000
Itay	14,647,000	Switzerland	8,621,000
Netherlands	132,679,000	United Kingdom	75,113,000
Norway	1,039,000		
NORTH AMERICA			
United States	$78,207,000	Costa Rica	$113,000
Canada	10,933,000	Cuba	2,081,000
British West Indies	523,000	French Colonies	237,000
Mexico	4,688,000		
SOUTH AMERICA			
Argentina	$4,466,000	French Guiana	$27,000
Brazil	4,293,000	Peru	925,000
Chile	1,657,000	Uruguay	784,000
British Guiana	409,000		
ASIA			
China	$10,804,000	Japan	$13,536,000
India	9,245,000	Korea	202,000
Dutch East Indies	5,514,000	Siam	261,000
French Indo-China	1,149,000		
OCEANIA			
Australia	$589,000	New Zealand	$1,733,000
AFRICA			
British South Africa	$987,000	Tunis	$238,000
Mauritius	590,000	Egypt	3,307,000
Algeria	1,645,000		

European countries have entered most conspicuously into international trade.

IMPORTS OF CHEMICALS INTO THE VARIOUS COUNTRIES

Table III shows the value of the imports of chemicals, drugs, dyes and fertilizers, into each of the various countries, which keep careful statistics as tabulated for the year 1906.

Summarized, the countries of the world purchase chemicals, drugs, dyes and fertilizers to the following extent:

Europe	$433,304,000
North America	96,782,000
South America	12,561,000
Asia	40,731,000
Oceania	2,322,000
Africa	6,767,000
	$592,467,000

To this international market the United States brought for sale in 1906 wares to the value of about $41,000,000, or 7 per cent of the whole.

Such is the field in which our manufacturers of chemicals are to extend their trade. It is the trade with Latin America, with Asia, and with Oceania that they should seek to win. The potential purchasing power of these portions of the globe amounted in 1906 to over $74,000,000. Unquestionably in Europe itself markets will open to us which have hitherto been closed.

The Empire of Germany has contributed to the international traffic, chemical wares valued at $111,000,000 annually, or 17 per cent of the entire amount. The United Kingdom contributed chemicals valued at $63,019,000, or 11 per cent of the total amount.

The markets which have hitherto secured their supplies chiefly from Germany are naturally the ones, under existing circumstances, in which the most earnest efforts should be made to cultivate new trade relations.

It would lead me too far to analyze in detail the markets for chemicals in the non-European countries, more accessible to our commerce. The detailed statistics of German exports show, however, very clearly the great extent of the territory which at present must seek its supply of chemicals from new sources.

I would, therefore, urge upon the manufacturers of chemicals who distinctly desire to enlarge their foreign connections and establish themselves solidly and firmly in the markets of the countries to the south and west of our borders, a most careful and detailed study of the import statistics of Latin America and Asia.

In frequent cases, where European wares have dominated the world's markets, our own production has been restricted and remained in a half-developed state.

Here there is abundant reason for us to make a valiant effort to break out from the chrysalis-like condition, unfold our wings to the fullest extent and meet not only the demands of the home market, but sally forth into the markets of the world. Such a bold and vigorous line of action is dictated more especially when the raw material required is found in abundance within our own borders.

Two such fields of industrial effort and industrial evolution are, at the present moment, pre-eminently worthy of our notice. Potash and dyestuffs are terms haunting the waking hours and banishing slumber from thousands of manufacturers between the Atlantic and the Pacific. The fertility of immense tracts of our land will sadly suffer unless means are found to replace the supplies of potash salts hitherto received from the mines of Germany.

Hundreds of the textile mills throughout the eastern half of the republic are facing a dyestuff famine, resulting from the complete cessation of imports of artificial colors from Germany since the middle of March last. This threatens a more or less complete stagnation in production. It involves under the most favorable conditions, such a dislocation of technical and commercial relations along the whole chain of connecting links, between the producer of textile fibers and the ultimate consumer of knitted or woven fabrics, that the daily loss, direct and indirect can be measured only by hundreds of thousands of dollars.

POTASH

In the case of potash, it is an economic absurdity that the farmers and manufacturers of this country should be so absolutely dependent upon a single foreign source. The painstaking, exhaustive studies of the Bureau of Soils in the Department of Agriculture show beyond the shadow of a doubt that the vast amount of potash stored annually in the boundless beds of kelp, floating off our Pacific littoral, can amply meet the world's demands. My own studies on this subject reveal a handsome margin of profit, should the attempt be made, on a grand scale, to garner this valuable crop, and replace for use as a fertilizer, the $10,000,000 worth of potash which we bring across the ocean from the mines of Stassfurt. The methods of extracting from kelp the technically pure potassium chloride to serve as a starting point for the manufacture of a large variety of salts of potash employed in the arts has now been so far advanced that at an early date we may witness the complete disappearance from our markets of foreign salts in this category.

Highly perfected now are, also, the methods for extracting in a soluble condition the potash content of our vast deposits of feldspar. Of exceptional interest is the recent process for releasing from its rocky fetters the potash in the form of the carbonate, the most convenient salt to use in taking up the manufacture of the other compounds of potassium as well as in the glass industry.

The progress in the utilization of our Western deposits of alunite is also noteworthy. Large quantities of potassium sulphate are now shipped regularly from Marysvale, Utah. The recent discovery of enormous deposits of alunite in the State of Washington, adjacent to tidewater, is of great moment, as the question of freights is notably simplified.

Of great interest is the process recently perfected by a young chemist of this city for rescuing from distillery waste the notable quantities of potash at present allowed to go to waste.

The current daily loss throughout the United States in distilleries employing molasses as raw material is estimated at 106 tons of pure K_2O. This is now transformed into a dry powder containing over 9 per cent of potash and a considerable amount of nitrogen. It serves admirably for the manufacture of composite fertilizers. A large plant is now being equipped at Boston for the utilization of this distillery waste product on an extensive scale.

In view of all this may I not confidently look forward to the early date when the production of American potash will have reached a point that permits a large export after having met all domestic demands? Within a decade or two this country should easily compete in the world's markets with the salts of Stassfurt, which hitherto has been practically the only source.

DYESTUFFS

Equally hopeful is the outlook for the ultimate solution of our dyestuff problem.

When it became evident that a "color famine" was imminent, the situation was quickly sized up by the little band of American manufacturers of artificial colors.

With true American pluck and enterprise, emancipation from dependence upon foreign-made intermediates was declared the slogan. At an expense of hundreds of thousands of dollars the necessary plant was erected to transform American benzol, toluol, naphthalene, etc., into the numerous intermediaries directly required for color production. Not an hour was lost in completing the new equipment. To-day one establishment is manufacturing nearly 60 per cent more than was the case in July, 1914; another has trebled its output of that date.

The movement has not been limited to an enlargement of existing works. A large group of new firms has sprung into existence and is actively engaged in the production of coal-tar intermediates, notably of aniline, which can also be used directly in the production of aniline black on hosiery and yarn.

Thomas A. Edison is a brilliant example of what Yankee foresight and intelligence can accomplish in such a field. Consuming normally large amounts of carbolic acid in the manufacture of the records for his phonograph, he suddenly faced a crisis. The price of the article had soared from 10 cents per pound to $1.50, and but little could be secured at that rate. Promptly Mr. Edison assured an adequate supply of benzol, the primary coal-tar "crude," from which carbolic acid can be prepared synthetically. This was accomplished by erecting at considerable cost the requisite "scrubbers" for the removal of benzol from the waste gas of by-product coke ovens. He was then in a position to embark extensively upon the manufacture of carbolic acid. Finding the venture so successful, he constructed the necessary plant for the manufacture of aniline. This proved to be also most profitable.

In solving so simply and effectively two leading phases of the coal-tar problem, Mr. Edison has blazed the trail for other daring pioneers, and has shown how simple is the primary series of operations necessary to build up a self-contained American dyestuff industry. There are now quite a number of well-financed companies which are daily increasing the volume of the output of coal-tar intermediates and which are turning their attention to the manufacture of finished dyestuffs. Chemists, consumers, and economists have vigorously attacked the entire problem. There is an insistent inquiry, "Why are we not making ourselves all of the colors required by American consumers of dyestuffs?"

The Department of Commerce has taken an active interest in the working out of the problem. It has done all in its power to stimulate and encourage the efforts now directed to build up an independent, self-contained American coal-tar chemical industry. It has collected and disseminated the requisite information for those planning to enter the new field. It has carefully and exhaustively studied the question of how far existing law can protect the young industry against unfair competition on the part of foreign rivals, when normal international relations are restored.

Gradually the decisive factors in the situation have been determined and outlined. They may be summarized as follows:

The United States possesses all the needed raw materials in abundance—in such amount that it could meet the demands of the world's dyestuff industry. It offers the largest existing market for consumption of dyestuffs.

Enterprise, inventive talent, and technical ability are present in abundance.

Capital is ready to embark in the new field in ample amount, and is daily being invested.

On the other hand, we lack the few skilled, experienced captains of industry, well-trained in this special field, and thoroughly well-equipped to organize and conduct the manufacture of colors on essentially the same basis as now exists in directing the gigantic factories on and near the Rhine.

There is also some hesitation on the part of capital to build up the industry on a magnificent scale, fully commensurate with the country's needs, until there is absolute certainty that laws will find their way to our statute books capable of effectually preventing any attempt to destroy the young industry on the part of foreign competitors.

This is, in fact, the one great IF, which for the moment blocks to some extent the rapid and healthful expansion of the domestic industry. With or without the leadership of men equal in technical and scientific equipment to the brilliant galaxy of those directing the European factories, we are bound to have our independent American color industry. The moment is impatiently awaited when the President of this republic shall affix his signature to a law making as impossible in foreign trade as it is now in domestic trade any attempt to crush, stifle and throttle a new industry on the part of competing rivals beyond the seas. When this moment arrives, capital in abundance is ready to back American enterprise in swiftly but surely laying the foundations for a permanent American coal-tar color industry. It may take a year or two to furnish one-half of the artificial dyestuffs now in current use; it may take four or five years before nine-tenths of the colors now regularly used in American textile and other factories are made from American benzol, toluol, naphthalene, phenol, anthracene and carbazol. But the day is coming as certainly as the sun will rise to-morrow morning from the waves of the Atlantic.

It is most refreshing to note the utter indifference to minor side-issues manifested by the men who are determined to build up this new industry. But a few years ago discussion would have centered about the tariff. To-day the men who are ready to finance a color industry, or to throw into it the best of brain and nerve, are asking simply for a fair show—to prevent a competitor from hitting below the belt. The vast multitude depending directly or indirectly upon an abundant supply of coloring materials are fast losing patience with the class of publicists who fold their hands in the face of a profound industrial crisis, and grumble because the determined and persistent pressure brought to bear by our State Department has not yet succeeded in inducing our friends in Berlin to allow the free exportation of dyestuffs to our ports. They show as little interest in those who murmur, "Raise the tariff and it will be possible to plan for a genuine American color industry." Their sympathies are with the red-blooded men of action who have worked out the details of this most intricate of problems, recognize fully its manifold difficulties and the multitude of obstacles in the path, and yet are ready for the fray.

I cannot but admire men of the type of J. F. Schoellkopf of Buffalo, the pioneer in this branch, whose name will go down in our economic history as the father of the American coal-tar chemical industry. With what energy and strategy during the past twelvemonth has he multiplied the working features of the magnificent plant on the shores of Lake Erie, freed himself technically from all dependence in the future on foreign-made materials, concentrated his efforts on a few of the staple, most essential colors, and thereby vastly magnified his output. Such wisdom and resoluteness have meant salvation from heavy loss to many a mill man, hesitating whether he should close the doors and dismiss his operatives.

A year ago, a modest color factory was in operation in Brooklyn, sadly hampered by the sudden inability to

secure the customary intermediate compounds from across the sea. One night last November it was destroyed by an explosion, accompanied by sad fatalities. Did Dr. William Beckers decide to wait for further developments in the great struggle to our east, or for congressional action, before he laid his plans? Not he! A million dollars were promptly expended in new constructions and in the requisite mechanical equipment for eliminating all dependence henceforth on material from European works. To-day he also is able to contribute bravely his share towards lessening the hardships of the textile industry.

I might mention, in passing, the notable enlargement of the coal-tar dyestuff works in the great establishment of Heller & Merz at Newark, the spacious new buildings of the neighboring Central Dyestuff Works, and the noteworthy effort within the past few weeks to materially broaden the scope of the Consolidated Dye Works, in Newark, under the energetic direction of the Hon. Herman A. Metz, whose patriotic desire to contribute his part in building up an American dyestuff industry is equalled only by his achievements of a year ago in securing for our users of colors ample supplies from Europe when stocks were dangerously low.

I can dwell upon these aspects of the dyestuff situation in but a hasty and cursory manner. I cannot, however, close without referring briefly to promising and fascinating efforts to create an American dyestuff industry, in a new and very literal sense of the word. Two new projects have interested me extremely. The appearance at this exposition of the Pearsite and the Petracine colors may possibly mark new starting points in the evolution of the color industry. . . .

And now, let me revert to my original theme. May we not all look forward with a fair measure of confidence to the exposition of 1925, when the directors of American coal-tar chemical works will report to us their sales of American-made dyes in the world's markets?

What has been accomplished with the products of our iron mines and our pine forests, as well as with the many triumphs of American mechanical genius, can surely be attained in the field of coal-tar chemistry by a similar use of resoluteness and energy, supported by the helpful action of the nation's lawgivers, in granting full protection against unfair practices on the part of foreign competitors.

Centrifugal Pumps.—The Lea-Courtenay Company, Newark, N. J., has issued catalog H-2, containing illustrations and descriptions of their centrifugal pumps of the turbine type, double-suction, single and multi-stage types and single suction, multi-stage type for varied lines of work.

The **Pensacola Tar & Turpentine Co.** of Gull Point, Fla., has sent us its latest list of oils for flotations, comprising eight different oils. This company makes a specialty of producing oils for flotation purposes. "It seems that from 10 to 30 per cent of pine products are desirable, if not quite necessary, on most ores."

The **Specific Heat and Heat of Fusion of Ice** have been determined by the Bureau of Standards at the request of the refrigeration industries. The results are given in Paper No. 248, the authors being H. C. Dickinson and N. S. Osborne.

The **Bureau of Mines** has issued Bulletin 94, United States Mining Statutes Annotated, by J. W. Thompson. This is a large work in two volumes and shows the status of every Federal mining law, both relating to metal mining and coal, oil, and phosphate. It may be had for $2.50 by applying to the Superintendent of Documents, Government Printing Office, Washington, D. C.

Recent Chemical and Metallurgical Patents

Iron and Steel

Electric Steel Refining.—If the electric furnace is to become of widest use for the manufacture of large-tonnage steel products (rails, structural steels, etc.), it must be in a process in which electric-furnace refining succeeds Bessemer converter or open-hearth treatment, and it is of utmost importance to reduce the combined cost of such a combination process to a minimum. The principal problem of any such duplex process is to determine the exact point where to stop one step and begin the next step. In ordinary steel manufacture the manganese contained in the pig iron is almost wholly lost through oxidation in the Bessemer converter or open-hearth furnace. Mr. William R. Walker of the U. S. Steel Corporation avoids this loss by stopping the heat of the oenverter or open hearth while a major portion of the contained manganese (above 0.1 per cent) is still present in the metal. The metal is then tapped and fed into an intermediate mixer which equalizes the manganese contact. From this mixer charges of desirable size are taken to the electric furnaces in which the metal is deoxidized, largely through the action of manganese. (1,155,849, Oct. 5, 1915.)

Alloys

Alloy of Platinum and Osmium.—A substitute for platinum-iridium or "hard platinum" is patented by Dr. Fritz Zimmermann of Newark, N. J., the patent being assigned to Baker and Company. The limited supply of iridium and its high price have created a demand for another hard alloy. By a series of tests it was found that the addition of osmium to platinum greatly increases the hardness. The percentage varies between ½ of 1 per cent to 10 per cent. Alloys with 10 per cent are only workable with difficulty. As far as hardness is concerned, one part of osmium is equal to two and one-half parts of iridium; the tensile strength is high, and the alloy is ductile and is also more resistant to the action of acids than platinum-iridium. The alloy of 98 per cent platinum and 2 per cent osmium can be used for jewelry work, being hard and tough, while alloys containing 10 to 6 per cent osmium will replace alloys containing 15 to 25 per cent of iridium for contact points in electrical apparatus. The platinum and osmium must be refined to a high degree of purity to remove impurities. The natural platinum which contains osmium, copper and iron cannot be used for this purpose. (Original 1,055,119, March 4, 1913; reissue 13,691, Aug. 10, 1915.)

Electric Furnaces

Abrasive for Grinding Steel.—An electric-furnace abrasive of oxides of aluminium, magnesium, and titanium is patented by Dr. Herbert T. Kalmus of Brookline, Mass., the patent being assigned to the Exolon Co., Cambridge, Mass. Abrasives consisting essentially of alumina are said to have been found too brittle for certain classes of steels, the cutting edges of the grains failing under compression before they become dulled. Experiments showed that pure alumina tends to crystallize with a coarse structure which it is very difficult to prevent by any of the practical devices for operating electric furnaces. Magnesium and titanium oxides in the proportion of their molecular weights, when fused with alumina in the right proportion, give a resulting product of very fine-grained, crystalline alumina, the spaces between and surrounding the individual crystals being filled with magnesium aluminate, magnesium titanate, and eutetics of these with alumina. This product possesses the proper qualities to give efficient cutting action on hard steels and other hard

metals. Neither the oxide of titanium nor the oxide of magnesium alone gives the desired combination of abrasive properties.

In commercial practice emery, or aluminous material, containing the oxides of magnesium and titanium in the right proportions, is mixed with carbon in sufficient proportion to reduce all impurities, charged into an electric furnace and fused. The stationary arc-type in which the electrodes are gradually raised is preferable. The iron oxide and silica content should be gaged to have a ratio of six to one in order to produce ferrosilicon as a by-product. By the fusion, a pig of segregated metals, resulting from the furnace reduction, is formed at the bottom of the furnace and a pig of abrasive material is formed in the body of the furnace above the metal pig; these may be allowed to cool in the furnace, then separated. An abrasive was prepared from emery which contained 95.5 per cent Al_2O_3, 1.5 per cent MgO, and 3 per cent TiO_2. This product was hard, tough, fine-grained, and practically insoluble in water and acid solutions. When working with hard varieties of steels it is desirable that the abrasive should not contain more than 3 per cent or less than one-half of 1 per cent magnesium or titanium oxide. Iron oxide and silica should not be present in excess of 1 per cent. The temperature of the furnace is kept high enough to reduce the iron oxide and silica, but below the reduction temperature of alumina, so as to prevent the formation of sub-oxides or carbides. This process is said to make possible the use of domestic emery ores, which had heretofore been found objectionable owing to their magnesium content. Usually the emery ores used have been foreign, which were practically free from magnesium oxide. (1,149,064, Aug. 3, 1915.)

Calcium Carbide from Carbide Fines.—When carbide fines have been utilized for directly remelting in an electric furnace and causing the material to solidify in masses, it has been found that the product was not of good quality, giving a low yield of acetylene. This was found to be due to a loss of carbon during the remelting, and the fines are difficult to smelt owing to their irregular conductivity. In a patent of HERMAN L. HARTENSTEIN of Constantine, Mich. (assigned to Continental Investment Co., Duluth, Minn.), it is proposed to mix the carbide fines with finely divided coke, charcoal or a suitable grade of coal and treat this mixture in an electric furnace. This can be accomplished in the ordinary types of electric furnace in much the same manner as calcium carbide is ordinarily made. The amount of carbon employed in the mixture should be enough to reduce moisture that is present to hydrogen, carbon dioxide to carbon monoxide, etc. In this manner reduction of the calcium carbide by oxygen or oxides is prevented. There should also be enough carbon present to transform any other calcium compounds present, like calcium hydrate, oxide, carbonate, etc., into calcium carbide. In practice the waste carbide or carbide fines are analyzed, since the composition varies greatly with age, state of fineness, etc. The amount of unchanged carbide is determined and also the amount of oxidants capable of affecting changes in the carbide. After having determined this the necessary carbon and carbide fines are mixed and fed into an electric furnace, where the mixture is heated and reduced to a molten condition. It may then be allowed to cool in the furnace or be tapped. The carbide is claimed to be of high grade and much superior to the dust used in its production. (1,152,506, Sept. 7, 1915.)

Preventing Blue Powder in the Electric Reduction of Zinc Ores.—A patent for preventing sulphidization of zinc vapors in the electric reduction of zinc ores has been granted to Mr. WOOLSEY MCA. JOHNSON of Hartford, Conn., and is assigned to the Continuous Zinc Furnace Company, Hartford, Conn. It is of interest in connection with the puzzling problem of preventing the formation of blue powder in the condensation of zinc reduced in electric furnaces. The presence of sulphur in the free state, as carbon disulphide, sulphur dioxide or trioxide causes a partical sulphidization of the zinc vapor, forming a coating which prevents the zinc globules from coalescing into liquid zinc. In this process the ores are first calcined, the charge being so proportioned as to give a resulting product analyzing about as follows: 30 per cent Zn, 10 per cent Pb, 2 per cent Cu, 15 per cent Fe, 8 per cent SiO_2, 4 per cent CaO, 1 per cent MgO, 3 per cent S. The roasting temperature is about 950 deg. Cent., and the conditions such that sulphates other than those of barium, calcium, and lead are decomposed.

The hot calcined product from the roasting operation is mixed with 15 to 20 per cent of soft coal. The fluxes for the final electric furnace treatment may also be added at this stage. The mixture is then fed into a preheater furnace of the continuous coal or gas-fired type such as the McDougall. In this preheater the $PbSO_4$, $BaSO_4$, Fe_2O_3, CuO are reduced to PbS, CaS, BaS, Fe and iron suboxide, and Cu. No reduction of ZnO should take place.

Other reducing agents might be used in place of carbon, such as hydrogen, carbon monoxide or hydrocarbons, for instance.

The hot product from the preheater is then charged, without access to the air into a continuous electric furnace, where the following reactions take place:

$$ZnO + C = Zn + CO$$
$$ZnO + Fe = Zn + FeO$$
$$ZnS + Fe = Zn + FeS$$
$$ZnS + Cu_2 = Zn + Cu_2S$$

The iron is absorbed by the slag, the sulphides of iron and copper are absorbed by the matte. Lead sulphide is reduced to Pb by the iron or copper. The sulphur of the BaS and CaS is taken up by the Fe and Cu, and the Ba and Ca enter the slag as silicates. A large excess of metallic particles is continuously descending through the charge and slag into the matte. These metallic particles effect the desulphidization of vapor, charge and slag, and the vapor leaves the furnace in the right condition for condensing to liquid zinc. It is, of course, necessary to use the right temperature, for if the furnace were heated as high as 1350 or 1400 deg. C., carbon disulphide, SO_2 or SO_3 might form, and the matte might also be slightly decomposed. (1,150,271, Aug. 17, 1915.)

Preventing Punctures in Flame-Arc Furnaces.—A method of preventing punctures in flame-arc furnaces is patented by EINAR TROYE of Christiania, Norway. It consists in allowing an air space between the outer iron cover of the furnace and the brick lining. Air is passed through this space at a suitable pressure and may later be used in the furnace if desired. More than one air space could be used with walls of asbestos interposed between them. This method is claimed to allow of a considerable reduction in the thickness of the brick wall and to make a completely puncture-free furnace, also avoiding any current loss in the earth. (1,148,343, July 27, 1915.)

Boron Nitride.—A process for making boron nitride is patented by Dr. GEORGE WEINTRAUB of Lynn, Mass., and assigned to the General Electric Co. In this process borax and a cyanogen compound such as a cyanide or ferrocyanide are finely powdered and mixed and then heated to 2000 deg. C. in an electrical resistance furnace. All products such as carbonates, cyanates,

and the excess of borax or boric anhydride are volatilized and boron nitride remains. The process is continued until no more fumes are evolved and a white stable product is left. The yield is 30 per cent and upwards of the theoretical. (1,135,232, Apr. 13, 1915.)

Electrolytic Furnaces

Alkali and Alkaline-Earth Metals.—An electrolyte of cyanide or cyanamide for the production of metallic sodium, calcium, etc., in an electrolytic furnace is patented by Mr. CHARLES E. ACKER of New York and assigned to the Nitrogen Company. According to a process of Ashcroft (801,199, Oct. 10, 1905) fused sodium chloride is electrolyzed with a molten lead cathode, producing an alloy of lead and sodium. In the Ashcroft process this lead-sodium alloy was then used as the anode in a secondary electrolytic furnace which had sodium hydroxide or chloride as an electrolyte and an iron or nickel cathode. The metallic sodium liberated at the cathode and rose to the top of the electrolyte. The present patent proposes to use a secondary electrolyte of sodium or potassium cyanide or cyanamide, claiming high efficiency at a convenient temperature, and an improved product. (1,142,220, June 8, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Notes on Homestake Metallurgy.—A paper by ALLAN J. CLARK supplementing a former paper before the Inst. of Min. & Met., London (*Transactions*, Vol. XXII, page 68, 1912-13), was presented at the A. I. M. E. meeting in San Francisco. The present paper deals with changes that have been made in Homestake metallurgy since the former paper was written. A flowsheet is given in Fig. 1.

A new mortar recently adopted retains the old inside lines so effective in maintaining a rapid discharge. All the front above the screen rest has been cut away; also a considerable portion of the back. The result is greater accessibility and increased safety to men when changing iron—it permits the use of longer bossheads and simplifies the care of feeders. A small chip tray of 4-mesh screen rests above the discharge screen and collects floating particles of wood. These are collected and burned, the ashes having a value of $300 per ton.

Table I shows the tendency of the unoxidized ore to amalgamate less readily than was the case in earlier years, and the tendency toward recovery of amalgam farther from the battery.

TABLE I.—COMPARISON OF AMALGAMATION RESULTS ON ORES OF DIFFERENT PERCENTAGES OF SULPHIDES

Column I. All mills, three-month period in 1910.
Column II. One mill, crushing unoxidized ore exclusively, three months, 1915.

Of the Total Recovery by Amalgamation, there was Recovered from:	I. Per Cent	Cumulative Per Cent	II. Per Cent	Cumulative Per Cent
Batteries	49.4	49.4	35.6	35.6
First-row plates	37.5	86.9	42.9	78.5
Second-row plates	4.4	91.3	8.1	86.6
Third-row plates[a]	2.3	93.6	3.5	90.1
Fourth-row plates[a]	0.9	94.5	2.0	92.1
Skimmings[b]	4.0	98.5	6.9	99.0
Trap sands	1.5	100.0	1.0	100.0
Percentage of ore value		71.7	....	69.7

[a] Only two mills (440 stamps) equipped with a fourth row of plates.

[b] The "skimmings" of the above table are recovered from re-treatment of the foul amalgam, sulphide particles, etc., removed from the cleanup sink during the cleanup of the chuck-block and plate amalgam.

In an effort to determine what relation, if any, exists between the amount of quicksilver fed to the batteries, the amount of bullion recovered, and the grade of the ore crushed, the records of all six mills were tabulated over a period of one year. While the experiment was without decisive results, the results of four mills, including those crushing ore of the two extremes in value, coincided reasonably well with a curve represented by the equation:

$$T=\frac{8.5\,B-H}{H}$$

when

T = Value of ore (dollars per ton).
H = Troy ounces of quicksilver fed to batteries.
B = Troy ounces crude bullion ($16 per oz.) recovered.

A detailed analysis of lost time in the stamp mills shows a percentage of 1.07.

COST OF STAMP MILLING

	Stamping	Amalgamating		Total
		Normal Charges	Rebuilding Plate House	
Operating labor	$0.0895	$0.0164	.....	$0.1059
Other labor	0.0033	....	$0.0064	0.0097
Power	0.0457	...	....	0.0457
Machinery	0.0628	.. .	.. ..	0.0628
Water	0.0315	...	...	0.0315
Sundry supplies	0.0097	0.0036 quicksilver 0.0042 silver plating 0.0003 miscellaneous	0.0059 silver plating 0.0018 lumber	0.0255
Total	$0.2425	$0.0245	$0.0141	$0.2811

Power at $30 per horsepower year; quicksilver at 50c. per pound; castings, 2½c. per pound; mill labor, $2.97 per 8-hr. shift.

REGRINDING PLANT DATA

Mill Number	1	2	3	4
Manufacturer	Denver Engr. Works	Allis-Chalmers Co.	Allis-Chalmers Co.	Hardinge Conical Mill Co.
Dimensions, feet	5 by 14	5 by 18	5 by 18	6 by 6
Speed, rev. per min.	27.0	28.5	28 0	26.5
Actual horsepower (motor input)	32.0	42.0	42 0	27.0
Fed from	Dewatering cone	Dorr classifier	Dorr classifier	Dewatering cone
Tons fed per day	98.0	138.0	133.0	93.0
Pebbles per ton	1.40	1.24	1.38	1.71
Tons to pass 100 mesh	41.0	52.0	49.0	34.0
Tons to pass 100 mesh per horsepower	1.28	1.24	1.17	1.26

REGRINDING PLANT: OPERATING COSTS FOR 1914

	Cost per Ton Fed to Tube Mills	Cost per Ton Reduced to Pass 100-Mesh Sieve
Labor	$0.0496	$0.1289
Pebbles and liners	0.0259	0.0673
Renewals, mills and cones	0.0074	0.0193
Machine-shop service	0.0037	0.0096
Silver plating	0.0077	0.0200
Sundries	0.0029	0.0075
Power	0.0292	0.0759
Total	$0.1264	$0.3285

Tons fed to mills, 152,106. Tons ground to pass 100-mesh sieve, 58,605. Cost of regrinding, per ton crushed in stamp mills, $0.0121.

Classification and aeration are two essentials for successful sand treatment. Aeration is necessary to prevent ferrous compounds removing oxygen from the solutions, and is accomplished by forcing air under slight pressure below the canvas filter. Laboratory tests indicate that on an average 75 cu. ft. of oxygen is absorbed by a ton of ore before its reducing action is corrected.

Although it had been recognized that high protective alkalinity was detrimental, it had been considered impossible to dispense with it entirely, or practically so. Eventually this was done, with improvement in extraction and decreased consumption of cyanide. These results were partly due also to another change made about the same time. Solutions of two strengths are used, that stronger in cyanide being used earliest in the treatment of a charge. When these solutions appear as

effluents, one portion is precipitated and the other brought to full working strength by adding cyanide, and returned to the extraction of another lot of sand.

"This custom is by no means unusual, yet wherever it is used the procedure seems to be to maintain the stronger solution at a fixed content of cyanide and to allow the weaker to vary in strength according as the varying losses in treatment may determine. This is wrong in principle. The critical strength is that below which the weaker solution will no longer dissolve its quota of gold, or, if dissolving it, will no longer freely yield it to precipitation. If the strength is greater than this, we may confidently expect some cyanide to be destroyed without giving compensatory service. In such circumstances, if the maximum working strength is reduced, the weaker solution will be automatically restored to the lowest economic strength; if it falls below this, a temporary increase in the maximum strength will restore it. In other words, cyanide should be added to the *strong* solution in accord with the determinations of strength made on the *weak* solutions. Thus, operating with a strong solution of variable strength and a weak solution also variable, but never far from its effective limit, it may be anticipated that little cyanide will be needlessly expended."

No. 1 SAND PLANT: OPERATING COSTS FOR 1914. TONS TREATED, 598,043

	Operating Labor	Other Labor	Power	Chemicals	Misc.	Total
Superintendence	$0.0081	.....	.....	.....	.....	$0.0081
Assaying	0.0033	.....	.....	$0.0004	$0.0006	0.0043
Transportation	0.0010	.....	.....	.....	0.0001	0.0011
Neutralization	0.0034	.....	$0.0002	0.0093	.....	0.0129
Classification	0.0086	$0.0002	0.0007	...	0.0008	0.0103
Treatment	0.0293	0.0011	0.0054	0.0541	0.0021	0.0920
Precipitating and pumping solutions	0.0055	0.0005	0.0005	0.0046	0.0006	0.0117
Heating	0.0007	.....	.....	....	0.0041	0.0048
Refining	0.0015	.....	.....	....	0.0022	0.0037
Miscellanies	0.0019	0.0009	0.0005	.....	0.0024	0.0057
Repairs[a]	.....	0.0121	.....	...	0.0072	0.0193
Power from H. M. Co.	.....	.....	0.0033	.....	.....	0.0033
Total	$0.0632	$0.0148	$0.0106	$0.0684	$0.0202	$0 1772

[a] Includes only larger items of repair work, necessitating the labor of a crew of carpenters.

Unit consumptions per ton of sand treated: Sodium cyanide, 0.257 lb.; zinc dust, 0.061 lb.; lime, 2.48 lb.; power, 1.09 kw.-hr.

Treatment of slime in the Merrill presses is identical in principle with that of sand, periods of aeration and treatment alternating. The minimum working strength is determined by the ability to precipitate the solutions. For a ten-day period the consumption of NaCN per ton of slime was: In treatment, 0.127; added for precipitation, 0.008; total, 0.135. The cyanide added for precipitation is usually added with the feed of zinc dust. An excessive amount of zinc dust is also necessary to insure clean precipitation of these solutions, entailing further expense in refining as well as in the first cost of zinc. These additional costs consume about 25 per cent of the profit of reducing cyanide consumption.

The tonnage of slime treated is measured by the "flow gravity" system, which the author elaborates as follows:

Procedure.—Valves on the two "sludge tanks" receiving the incoming stream of pulp are closed. The depth of slime in each tank and the time are noted. The stream of pulp is now diverted to tank *A*, the discharge valve from which is closed, the presses being served with pulp delivered from tank *B*. When tank *A* is filled, the time and volume are noted, the valve from *B* is closed, the pulp turned to tank *B* and the discharge valve from tank *A* is opened. These alterations continue throughout the period assigned for measuring. Changing, which is at intervals of about thirty-five minutes, is not instantaneous, but the actual measurements cover 90 per cent of the total time, sufficient to insure a correct average rate.

At half-hourly intervals the stream of pulp is cut by a mechanical sampler, a 5-gal. bucket being filled and the weight of pulp determined. These determinations

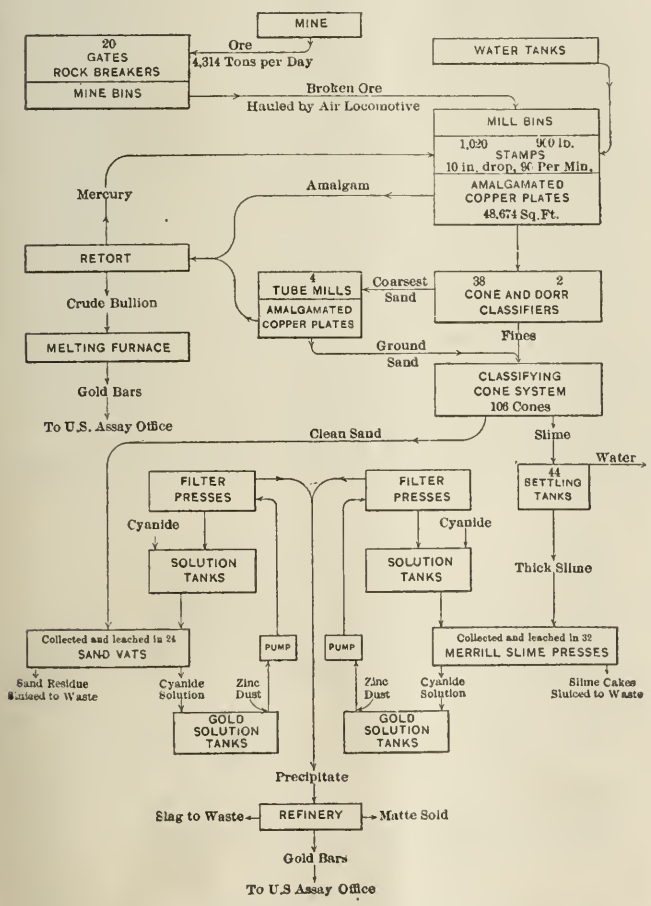


FIG. 1—FLOW SHEET SHOWING ORE TREATMENT AT HOMESTAKE MINE

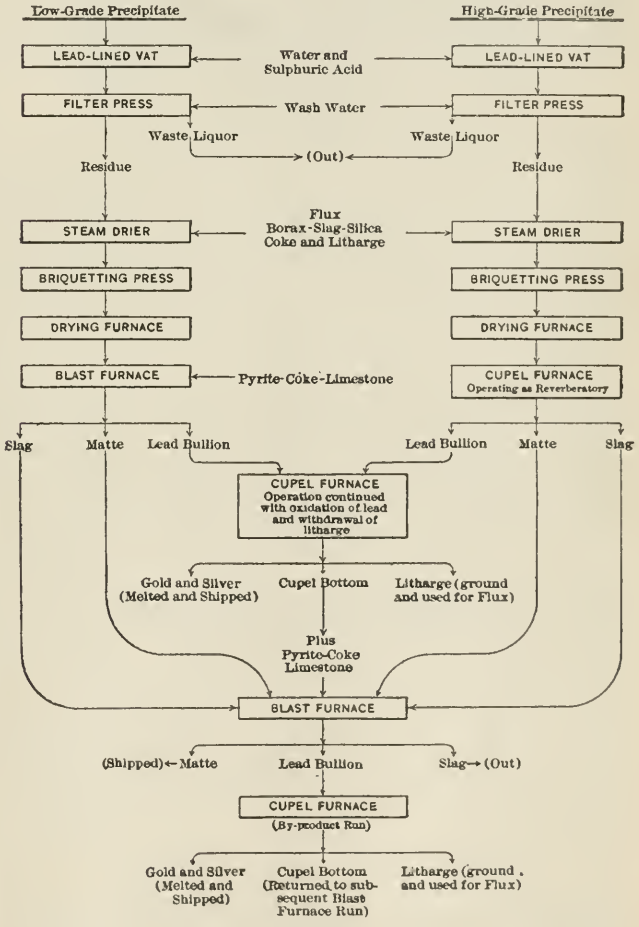


FIG. 2—REFINING OF PRECIPITATE AT HOMESTAKE

are averaged. A specific gravity determination is made on the average sample of slime.

Estimate of tonnage treated between noon of April 8, 1915, and noon on following day:

	Feet	Cubic Feet
North Sludge Tank:		
Total depth pulp to tank	132.667	
Deduct, lime water	1.078	
Balance, slime pulp	131.589	
131.589×518.85 (cu. ft. per foot of depth)		68,274.95
South Sludge Tank:		
Total depth pulp to tank	125.334	
Deduct, lime water	1.003	
Balance, slime pulp	124.331	
124.331×514.42		63,958.35
Total cubic feet for 22.05 measured hours		132,233.30
Estimated pulp for 24 hr		143,927.28
Correction for excess pulp in tanks at end of test		3,590
Cubic feet of pulp run to presses during test		140,337+

During the test, 39 determinations were made of the weight of 5 gal. of pulp. The average of these determinations gave the following data:

Percentage of solids in pulp	33.68
Weight of 1 cu. ft. of pulp	80.60 lb.
Solids in 1 cu. ft. of pulp	27.146 lb.

Total solids to presses during test = 140,337×27.146 = 3,809,600 lb. = 1,904.8 tons, which was divided among 73 presses, making the average charge of 26.09 tons.

Slime Plant Operating Costs for 1914

	Operating Labor	Other Labor	Power	Chemicals	Miscellaneous	Total
Superintendence	$0.0093	.....	.....	.....	.....	$0.0093
Assaying	0.0021	.....	.....	$0.0005	$0.0005	0.0031
Thickening	0.0033	.....	.....	.....	0.0001	0.0034
Neutralization	0.0055	.....	$0.0004	0.0144	.....	0.0203
Treatment	0.0342	$0.0027	0.0152	0.0433	0.0119	0.1073
Precipitating and pumping solutions	0.0039	0.0006	0.0016	0.0096	0.0008	0.0165
Heating	0.0004	.....	.....	.....	0.0013	0.0017
Refining	0.0026	.....	.....	.....	0.0040	0.0066
Miscellanies	0.0057	0.0009	0.0012	.....	0.0010	0.0088
Repairs[a]	.....	0.0042	.....	.....	0.0026	0.0068
Total operating	0.0670	0.0084	0.0184	0.0678	0.0222	0.1838

[a] Minor repairs are carried as Miscellanies; heavy items of repairs, necessitating the presence of carpenter's crew, are included here. Press cloths cost $0.0100 per ton of slime treated.

Unit consumptions per ton of slime treated: Sodium cyanide, 0.161 lb.; zinc dust, 0.118 lb.; lime, 3.48 lb.; hydrochloric acid, 0.393 lb., costing $0.0093 per ton treated; power, 1.15 kw.-hr.

Copper

Hydro-Electric Treatment of Copper Ores.—A research by Robert R. Goodrich on the treatment of an Arizona porphyry ore by a process including the following steps: Oxidizing roast, leaching with sulphuric acid and electrolytic precipitation of the dissolved metal is given in a paper read at the San Francisco meeting of the American Institute of Mining Engineers. The author gives the following epitome of his rather extensive paper:

1. The most suitable temperature for roasting the Arizona porphyry copper ore, containing sulphides, in order to render it amenable to acid leaching methods, is between 600 deg. C. and 725 deg. C. The more finely ground the material the shorter the time required for the roasting so as to produce the maximum amount of soluble copper: materials which will pass through a 20-mesh screen and remain on 80 mesh require about 2 hr. roasting at 600 deg. C. to 725 deg. C.; and when ground to pass through an 80-mesh screen the time required is about 1¼ hr. If the roasting is concluded at temperatures above 800 deg. C., the oxidized copper is converted into a compound which is insoluble in dilute sulphuric acid. The longer the roasting is conducted above 800 deg. C., the greater the amount of insoluble copper produced.

2. A heated solution is necessary to leach efficiently the copper from the roasted material. A 10 per cent H_2SO_4 solution at 100 deg. C. leached out, in from 3 to 6 hr., all the copper from all roasted materials (through 40 on 80 mesh, through 80 mesh, whole through 20 mesh), except material through 20 on 40 mesh, in which case the extraction was not so high.

3. The nature of the anode is an important factor in securing depolarization by sulphur dioxide gas.

4. Depolarization with consequent saving in power is accomplished when using sulphur dioxide gas with a carbon anode, while there is no depolarization with a lead anode.

5. The depolarization by sulphur dioxide gas, even with carbon anodes, does not reach the theoretical amount, being between 45 and 65 per cent.

6. The amount of depolarization effected by sulphur dioxide gas when used with carbon anodes varies with the current density, being a maximum at low current density.

7. The method of introducing the sulphur dioxide gas into the cell is unimportant. All that is necessary is that it be introduced in some way, and in such quantity that the electrolyte is saturated with the gas, so that there is some escaping by bubbling at the surface.

8. A smoother deposit of copper forms when using sulphur dioxide gas as a depolarizer than when not using it.

9. In the electrolysis of an acid solution of copper sulphate, when sulphur dioxide is not supplied to the cell and when one is endeavoring to carry electrolysis to the point of complete extraction, a soft spongy deposit begins to form on the cathode before the complete extraction of the copper is effected. There is also a considerable rise in polarization when the copper contents of the electrolyte becomes low.

10. In the electrolysis of an acid solution of copper sulphate, when sulphur dioxide is supplied to the cell, the copper contents of the electrolyte may be reduced to a very small trace with the formation of a good, firm cathode, without rise in polarization toward the end. Current density and energy efficiency remain high to the end. It is only when prolonging the operation beyond the time when but a small trace of copper remains that sulphide of copper forms as a thin coating on the cathode.

11. Lead anodes do not peroxidize or deteriorate appreciably when used with or without the introduction of sulphur dioxide into the electrolyte.

12. A novel idea—step arrangement of process—makes feasible the depositing of copper continuously, while the copper contents of said electrolyte in the respective steps remains constant. A plant composed of several steps of such cells may be operated so that a liquor strong in copper flows to the plant continuously, and the liquor which outflows from the plant is depleted of its copper.

13. The circulation of the electrolyte by the step arrangement increases the current efficiency. Such rapid circulation is not possible in plants as ordinarily arranged.

Lead

High-Lime Slags in Lead Smelting.—A discussion by S. E. Bretherton of the advantages of using more lime and less iron in the smelting of lead ores for the purpose of neutralizing silica was given in a paper before the American Institute of Mining Engineers at San Francisco. The author gives Anton Eilers credit for introducing this departure in 1878-79. The use of lime was less expensive and enabled the metallurgist to make a more silicious slag of lighter specific gravity which contributed to a better separation of metal and matte. It also prevented the formation of "sows" in the lead crucible. When smelting arsenical ores, the use of high-lime slags resulted in the production of less speiss. With the smelting of sulphide ores in Colorado and Utah, matte became a by-product and arsenic gave less trouble. It was generally supposed that the arsenic was taken up in the matte and finally lost in its treatment. The author believes that this was true to a certain extent, but gives the following personal experience to show the effect of high-lime slags in eliminating arsenic.

"The ore to be smelted contained an average of about 3½ per cent lead, 6½ per cent iron, 2½ per cent manganese, 7 per cent zinc, 21 per cent lime, 11.7 per cent magnesia, 8½ per cent silica, 1 per cent alumina, 3 per cent arsenic, and only a trace of sulphur, together with a very small amount of ore, which we called our lead ore, from another mine averaging 11½ per cent lead, 20 per cent iron, 4 per cent zinc, 3 per cent lime, no manganese, no magnesia, 30 per cent silica, and only a trace of either arsenic or sulphur. From this it can be seen that there was more than enough arsenic to make a large proportion of speiss (especially as we smelted regularly considerable speiss containing gold and silver from some old slag dumps in the neighborhood), and no sulphur to make a matte to absorb it. At the same time, the bulk of the ore being so low in iron and manganese and high in lime and magnesia, I was compelled to make a slag very rich in lime and magnesia. The result was that we produced no speiss or matte, excepting once for a few hours when we fed in some sulphide ore to see what the results would be.

"The only detail in our practice which differed from the ordinary method of smelting was to cupel our bullion for shipment until it was rich in gold and silver, so as to use the lead as litharge over again in the charge. The fact that we were able to get rid of the arsenic in the ore and speiss from old slag dumps and make a comparatively clean slag led me to believe that the high percentage of lime base in the charge and the lack of iron with which the arsenic could combine, resulted in the volatilization of the arsenic, this action no doubt being assisted by the oxidizing influence of the litharge used. While our gold and silver losses were satisfactorily low, our lead losses were very high, which was to be expected when using the lead over and over again in such an oxidized mixture and keeping the coke consumption as low as possible. Coke was the only reducing agent used."

Fuels

Oil Fuel for Heating, Melting and Heat Treatment of Metals.—A paper by W. N. BEST describing some of the applications of oil-firing in boilers for power plants and in commercial furnaces of special design for melting metals and heat treatment of metals, was presented at the San Francisco meeting of the American Institute of Mining Engineers. The paper contains a number of designs of furnaces and calls attention to the necessity for avoiding rule-of-thumb methods in applying oil combustion.

"There has been a greater development in furnace construction during the past four years than in all the world's previous history. It requires 2009 cu. ft. of air to furnish the oxygen requisite for the combustion of 1 gal. of oil. Only about 20 per cent of this air is oxygen, while the other 80 per cent is nitrogen and other gases which unfortunately must be heated up to the same temperature as the furnace, but, for economy's sake, must be expelled as quickly as possible. It is therefore necessary that the furnace construction be such that the consumed and inert gases will be expelled at once. The combustion chamber should be so located and of such form and proportions as to insure perfect reverberation of the heat, while aiding in the quick expulsion of the gases. Only one burner should be used on any billet-heating furnace, no matter whether the charging space be 12 by 18 in. or 8 by 24 ft. in size. For a regenerative melting furnace two burners are necessary; but of course only one burner is in operation at any one time. In all other melting furnaces, whether the bath be 2 ft. square or 20 by 140 ft., whether the product requires an oxidizing or a reducing flame continuously or alternately, only one burner should be used. Additional burners make the operation of the furnace too complex. While the operator may strive to run them all alike, some will be giving an oxidizing and others a reducing flame, thereby impairing the efficiency of the furnace.

"In the designing of furnaces the question is not how many burners can be used, but how few will do the work. A poorly constructed furnace will ruin the efficiency of the best oil burner ever made, while a poor burner will ruin the efficiency of the finest furnace ever designed. It is as impossible to cover a flat furnace bottom or charging space with a round flame as it is to fill a square hole with a round plug. To obtain the highest efficiency and strictest economy it is necessary to have a good furnace, scientifically designed and constructed, as well as a superior type of oil burner."

Viscosimeters

BY R. F. MACMICHAEL

Viscosimeters are instruments for measuring the viscosity of fluids. They operate on two general principles.

First.—The *time* required to produce a definite relative movement of the fluid particles under a given force.

Second.—The *force* required to produce a definite relative movement of the fluid particles in a given time.

Familiar examples of the application of the first principles are:

a.—Long capillary tube, used by scientists.

b.—Short-tube commercial instruments, as Saybolt, Engler and Redwood.

c.—Falling bodies within the fluid, as Arnold, Ladenburg and Flowers.

d.—Rising bubble.

e.—Retarded surface, as Doolittle and Stormer.

In each of these instruments the time required for a definite movement of the fluid particles to take place is noted.

The acting force in each case, except that of Doolittle, is gravity. This may be the weight of the fluid itself, or the weight of a foreign body acting within or upon the fluid, or buoyancy of an air bubble. In the case of Doolittle, energy is stored up in a steel spring, and allowed to expand itself in rotating a disk.

In well-designed instruments of this class, the control of the acting force is almost absolute. However, the time required to make a test is frequently a drawback in the use of the instrument, and the difficulties of maintaining an exact temperature during the test are often very serious.

The fluid must usually be strained before testing. On very viscous fluids, this necessitates heating. Small particles of foreign matter within the instrument may

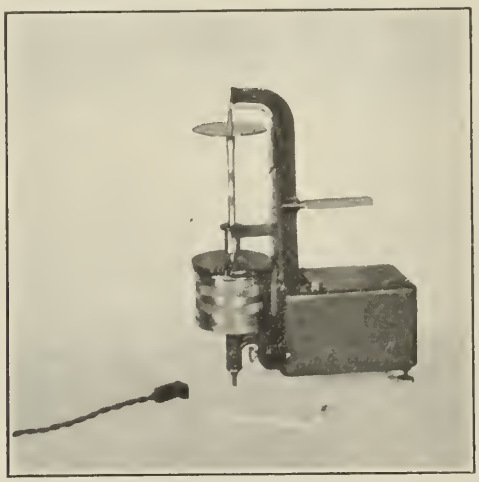


FIG. 1—VISCOSIMETER ASSEMBLED

interfere with proper action, and at times will introduce very large errors.

It is only rarely that colloidal or glue-like substances, or suspensions of finely divided solids, such as clay slips, can be handled successfully in these instruments.

Results are usually expressed in seconds of time. Even in the simplest forms of instruments, elaborate and involved calculations are required to reduce the readings to scientific units, while most of the instruments noted above are not susceptible even to such calculations. In the latter case the results are expressed in an arbitrary manner in empirical units.

The personal equation is large, and considerable care and skill are required if accurate results are to be obtained.

Viscosimeters of each of the above types have been before the public for many years. Up to the present it has not been found possible to combine in any one instrument based on the first principle all of the essential features required in a viscosimeter for general scientific and commercial use.

The most prominent examples of instruments based on the *second* principle are those of Couette, Clark and MacMichael.

In each of these instruments a cylinder or disk is suspended in a cup of fluid, and either the disk or the cup is revolved, and the torsional force noted.

Couette's experiments were conducted at an early date, and though the principles involved were sound, mechanical difficulties were encountered which proved

quite insurmountable at the time of its development.

In the more recent Clark machine, the tangential force applied to the rotating member is measured. This instrument under proper conditions gives excellent results, but the construction introduces mechanical complications which render it unsuitable for general use.

In the MacMichael viscosimeter, the force exerted by the rotation of the fluid itself on the stationary

FIG. 2—CUP AND PLUNGER REMOVED FOR CLEANING

member is measured. This force is equal and opposite to that applied to the rotating member.

The construction is simple and durable. Operation is rapid and accurate, and results are expressed directly in scientific units.

The photograph in Fig. 1 shows the machine assembled and ready for a test. A disk is suspended in the cup of fluid by a torsion wire about ten inches long, running down through the stem of the plunger, and fastened near the bottom.

The head of the torsion wire is triangular, and is held between two grooved pins at the top of the standard. The cup and plunger may be removed and replaced without manipulating any catches or fastenings.

Fig. 2 shows the cup and plunger removed for cleaning. All surfaces are smooth and rounded and may be cleaned with the greatest ease.

The cup is oil jacketed, being formed of two pieces of heavy spun brass. Within the oil jacket is immersed an electric heating coil. This coil draws current from the same line as the motor, only one connection being necessary.

The fluid to be tested is heated in place, no other heating device being required. The operation is very rapid. Stirring is effected by a slight vertical movement of the plunger.

For low-temperature work, the fluid and the adjacent parts are chilled in an ice bath or brine solution.

A bent thermometer inserted through an opening in the cover indicates the temperature, the bulb being immersed in the fluid. The temperature during test may be controlled within a small fraction of 1 deg. Fahr.

The graduated dial at the top of the plunger is secured to the stem by a friction disk, permitting the adjustment of the zero mark to its proper location. The fine adjustment is effected by means of the steel wire pointer at the head of the standard.

The same figure shows the dash pot on the stem of the plunger. This device is frictionless and automatic in action, and requires no attention from the operator. Its function is to check incipient vibrations and to permit quicker readings by damping the action.

In Fig. 3 the standard and hood are thrown back, showing the driving mechanism. The speed control is of the familiar phonograph type and gives excellent results. The motor is specially wound for this service and is furnished either for alternating current or direct current, for use on ordinary lighting circuits. Variations in voltage do not affect the accuracy of the determination.

In operation, the cup is filled to the mark on the side with the fluid to be tested. This requires about 100 c.c. The cover is put on and the thermometer inserted.

By means of the heating coils the temperature is raised to nearly the desired point. As expansion of the fluid will probably have taken place, the excess fluid is removed by means of a pipette furnished with the machine. This automatically fixes the proper level without further attention from the operator.

The temperature is brought exactly to the desired point, the thermometer removed and the motor started. Within a few seconds the dial will have come to rest, and will remain steadily at one point. The deflection noted is the viscosity of the fluid.

This entire operation is very rapid, so that the drop in temperature on ordinary work is entirely negligible.

For extreme accuracy, the temperature may be raised slightly above the desired point, and an allowance made for the drop up to the moment of reading. This will seldom be found necessary in actual practice.

The readings are in degrees of angular deflection, 300 deg. to the circle, designated as deg. M. The practical working unit is 1/1000 of the absolute unit.

FIG. 3—STANDARD AND HOOD THROWN BACK TO SHOW DRIVING MECHANISM

As water at 20 deg. C. or 68 deg. Fahr has exactly 1/100 of the absolute unit of viscosity, water at this temperature reads 10 deg. M.

Thus by shifting the decimal point practical units, absolute units, and specific viscosity may be obtained at one reading. Readings are taken directly from the dial, no intermediate calculations being required.

Gold plated torsion wires are supplied. These wires are of the very highest grade steel. They are extremely strong and their elastic properties are not affected by use. The heads are solid and will not break.

Torsion wires ordinarily give water as 10 deg. M and may be used up to 500 deg. M. This covers the range of most liquids ordinarily to be tested.

For extremely thin and extremely thick liquids, lighter and heavier wires giving readings for water of 100 deg. and 1 deg. respectively, are supplied. This covers every range of viscosity up to about 5000 deg. M, or 500 times that of water.

Calibration of the instrument is effected by testing with a standard fluid of known viscosity. Sugar syrup is used for this purpose. Water may be used for calibrating, but this is not advisable as it is too thin for the best results.

Should the reading of the dial, on test, be found to vary slightly from the correct value, the speed of rotation of the cup is altered by means of the speed control screw at the lower front of the machine.

The deflection of the dial will vary directly as the speed, other factors being constant, and the correct indication may be obtained. When calibrated accurately for one value, the readings will be correct for any other value.

The accuracy of the instrument under ordinary working conditions should be well within an error of ½ per cent above or below the true value. For extremely accurate work, extra precautions should insure results within a small fraction of this error.

As the time required for a reading is extremely short, determinations may be made on suspensions, such as clay slips, which settle rapidly.

Thus, the determination of the plasticity of clay by the MacMichael method is readily made by the use of this instrument. The instrument was originally developed for this particular purpose.

Colloidal solutions may also be handled successfully. This includes glues, gums, starch solutions, gelatine, and other similar materials. Likewise, the viscosity of complicated mixtures such as catsup, or other food materials or chemical substances, may be readily determined. Straining is unnecessary as small particles of foreign material do not in any way affect the accuracy of the determination.

The instrument, with its thermometer and pipette, is complete in itself. No stop watch is required, and no gas burners or other heating device, and no dippers, strainers, graduates, flasks or other parts except as noted.

Skilled labor is not required in its use, as any careful operator may learn to use it in a very short time. The personal equation is small.

The entire machine is built in the most substantial and durable manner, and is guaranteed by the builder.

It is believed that this instrument offers an accurate, rapid, convenient and thoroughly satisfactory means for determining the viscosity of fluids.

Seattle, Wash.

A New Vacuum Pump

Many processes, such as the various vacuum filtration systems now in general use in the mining and metallurgical field, require a vacuum. The modern powerhouse equipment invariably includes a condenser plant, the efficiency of which depends upon the degree of vacuum within the condensing apparatus.

For maintaining this vacuum and for general service in other lines where a high degree of vacuum is desired, the Ingersoll-Rand Company, 11 Broadway, New York, has recently introduced a complete line of steam and power-driven, duplex-type, "Imperial" vacuum pumps.

In general design these machines follow that of the "Imperial" air compressors, a type with which engineers and power plant operators are long familiar.

The vacuum cylinders, as will be seen from the sectional illustration, are different from those ordinarily met with. The intake valves are of the Corliss type, so placed in the cylinder head that the clearance is exceptionally low. This is a desirable feature in that the air trapped in the clearance spaces at discharge pressure will not reach such a volume, upon being expanded to intake pressure, as to greatly limit the pressure reduction which may be obtained. The action of the valve is positive and quick and, its action being independent of the cylinder and intake pressures, the pressures within and without the cylinder are as nearly equal as possible.

The intake ports are larger and direct, which together with the water jacketing of the valve tends to cool the intake gases.

The discharge valves, which are of the "direct-lift" poppet type, are placed in the bottom of the cylinder heads so that any entrained moisture or water is imme-

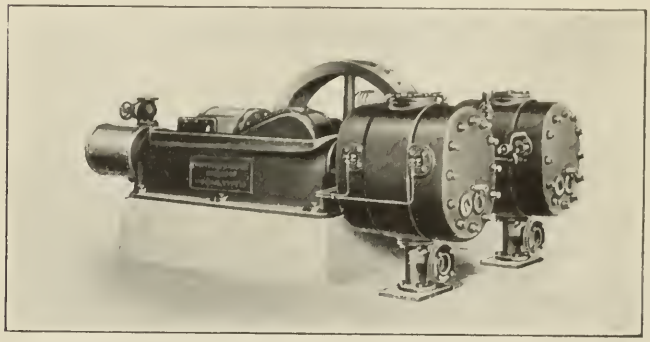


FIG. 1—STEAM-DRIVEN VACUUM PUMP

diately discharged, a feature that makes for safety in handling moist or even saturated vapor. Clearance at the point of discharge has been reduced by making the valve partially fill the port in the cylinder head. These discharge passages are also water jacketed.

The cylinders are said by the manufacturer to meet fully the requirements of satisfactory and efficient operation. The air passages are unobstructed. Tie bolts pass from head to head and hold cylinder and heads tightly assembled. Both cylinder and heads are completely water jacketed, which is said to be an essential feature in the design of vacuum pumps, as the high

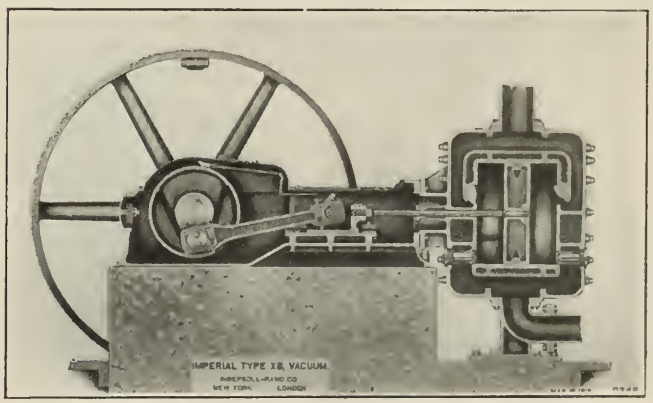


FIG. 2—SECTION OF VACUUM PUMP

ratios of compression tend to create high discharge pressures unless the heat is removed as generated.

The unusually low clearance in "Imperial" vacuum pumps has been obtained, not by dangerously close piston clearance, but by the correct design of the valves and valve ports.

Owing to the extremely low clearance, the complete water jacketing, the use of mechanically operated Corliss inlet valves and other refinements of design the manufacturer guarantees the easy maintenance of a vacuum of within ½ in. of barometer.

The running gear, that is, the main frame with its inclosed reciprocating parts, the crank shaft, connecting rod, crosshead, valve gear and wheel on both belt

and steam-driven machines are of the same design as the "Imperial" air compressor. Lubrication is by the bath system, providing automatic flood lubrication, yet retaining by the removal of covers from the casing, all the points of accessibility of the open type of machine. When operating the flywheel is practically the only visible moving part, yet the entire mechanism is readily accessible while in motion.

The Imperial vacuum pump occupies less floor space than similar capacity machines of the straight-line type, due to its duplex construction and to the fact that its speed of operation is higher.

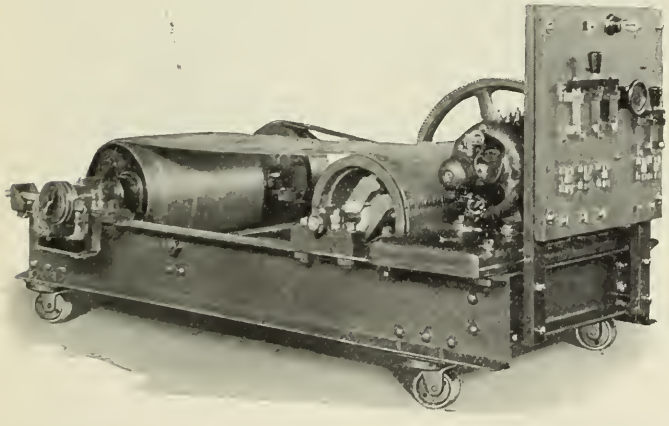
In reality a duplex machine such as this is two identical units of like capacity united by one common frame with cranks at 90 degrees. This makes it possible, should requirements fall temporarily below that for which the equipment was originally installed, to remove one connecting rod and the operation of one-half the machine discontinued, while the other half operates at its rated speed and hence its utmost efficiency, displacing, however, one-half the vapor the entire machine is capable of handling.

These machines are built in capacities from 798 to 7048 cu. ft. per minute, both for atmospheric and low-pressure (5 lb.) discharge.

The manufacturer claims for these vacuum pumps that they operate practically independent of attention and are thoroughly efficient and economical machines for maintaining a high vacuum.

New Portable Magnetic Separator Outfit

The accompanying illustration shows an interesting portable magnetic separating outfit built for the Graphite Lubrication Co., of Boundbrook, N. J., by the Cutler-Hammer Clutch Co., of Milwaukee. The separator is used for separating magnetic particles of iron, etc., from brass in various parts of the plant. The outfit is moved to the point where a separation is to be made and the mixed material of brass, iron, etc., conveyed onto the belt. The brass is projected beyond the



PORTABLE MAGNETIC SEPARATOR OUTFIT—THE MAGNETIC PULLEY IS SHOWN AT THE LEFT

pulley freed from magnetic pieces since the latter stick to the belt in passing over the magnetized pulley and are dropped below where the belt leaves the pulley.

This installation is particularly intresting, as in this plant only alternating current was available. The direct current for the magnetic pulley is furnished by a small 110-volt generator which is driven by the same alternating-current induction motor that drives the pulley. The small panel mounted at one end of the frame carries the three-pole motor knife switch and fuses, the double-pole generator knife switch and fuses, back-of-board type dynamo field regulator and pilot lamp.

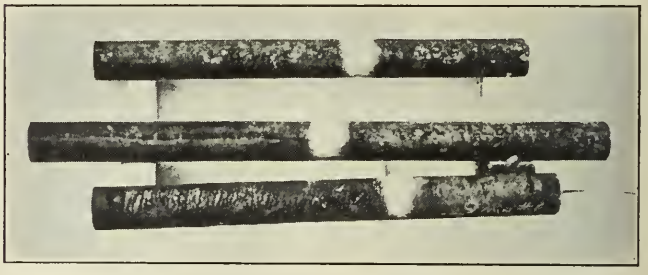
Welding Defective Cores in Paper Mill

The St. Croix Paper Company of Woodland, Me., was formerly throwing all broken and defective paper cores on the scrap pile. Much of this material was sold as junk at the best prevailing market prices. Many carloads of broken and defective cores had been disposed of in this manner before it was discovered that all of them could have been made as good as new by employing oxy-acetylene welding.

By using the Prest-O-Lite process of oxy-acetylene welding, broken cores similar to those shown in the illustration are now repaired in nine minutes. No filling material is used as a method has been found for handling the welding operation so that sufficient strength can be obtained with the material flowed into the weld from the pipe itself. Occasionally, however, a small quantity of filler rod has to be added to insure a joint that will be as strong as the rest of the core itself.

The two sections of pipe are prepared by simply cutting off in a machine with the regular cutting-off tool. The ends of the pipe are not beveled as the extra metal is needed where filling rod is not added.

The cores are steel tubes 3 in. in diameter and average about 50 in. in length. During the welding operation they are slipped over an iron arbor of the same



BROKEN CORES IN PAPER MILL WELDED BY OXY-ACETYLENE PROCESS

diameter as the shaft on which the roll is designed to run to insure perfect alignment with the longitudinal center.

As these cores accumulate very rapidly in the enormous production of the St. Croix Paper Company, it is stated that enough material, heretofore scrapped, is now on hand to furnish several years' supply of new cores without making it necessary to draw on any new material at all.

Tests of welded paper cores indicate that the reclamation process does not affect the original strength in the least—the welded portions stand the punishment incident to rough handling during continual shipping, although frequently the *original* metal in the tube is broken.

Former methods at repairing these damaged cores were very unsatisfactory. One method was to make a hammered weld in a blacksmith forge, first preparing the ends of the rolls by beveling one piece on the inside and the other on the outside so that they fit together snugly, making what was practically a lap weld. This method was exceedingly troublesome.

It is estimated that 250 lb. of coal was used daily in maintaining the fire for the blacksmith's welding operation and only a small number of cores could be repaired in a day as compared with the more economical method of welding by the oxy-acetylene process.

In view of the low cost of the oxy-acetylene welding equipment required and the greater speed with which the repair of broken cores is accomplished, the saving effected by the St. Croix Paper Company is considerable.

Personal

Mr. **Edward L. Brayton**, president of the Pelton Water Wheel Co., San Francisco, Cal., has recently spent some time in New York City.

Mr. **Russel A. Cowles** has resigned his position as a vice-president of the American Brass Company and has become associated with the Buffalo Copper & Brass Rolling Mill, Buffalo, N. Y., and has also recently been elected president of the Metals Trading Corporation.

Mr. **J. V. N. Dorr** was recently in New York, having spent the summer in San Francisco and on the Pacific Coast.

Dr. **James Douglas** of New York has donated $150,000 to McGill University, Montreal, for the erection of a students' residence. He has also been offered the position of Chancellor of Queens University, Kingston, Ont.

Mr. **L. V. Emanuel** has become associated with the River Smelting & Refining Co., Florence, Col.

Professor **W. S. Franklin** has resigned as professor of physics at Lehigh University and will make a tour of the universities of the South and West during the coming fall and winter; he offers to give, in connection with this trip, a number of theoretical and experimental lectures on some needed additions to the subject matter of theoretical mechanics; on wave motion and oscillatory motion; on electric waves; on some phenomena of fluid motion and the curved flight of a base ball, and on "Bill's School and Mine." Professor Franklin's desire is that payment be made for these lectures sufficient to cover the expenses of the trip. Among the lectures to be delivered is also that on some mechanical analogies in electricity and magnetism by which the brilliant author aroused so much enthusiasm at the Atlantic City meeting of the American Electrochemical Society last spring. Professor Franklin's address is care of Columbia University, New York City.

Mr. **Edward Hamilton**, formerly assistant general superintendent of the Duquesne Works of the Carnegie Steel Co., has been appointed general superintendent to succeed Homer D. Williams, who has been elected president.

Mr. **W. E. Hardy**, formerly connected with the Diamond Rubber Co. and the B. F. Goodrich Co., has lately been appointed sales manager of the Boston Belting Co., Boston, Mass.

Mr. **J. E. Johnson, Jr.**, has been elected chairman of the New York Section of the Mining and Metallurgical Society of America. Mr. A. H. Rogers has been re-elected vice-chairman and D. M. Liddell has been re-elected secretary-treasurer.

Mr. **Robert M. Keeney** has accepted a position with the Standard Chemical Co., Canonsburg, Pa., producers of radium.

Mr. **F. C. Newton** has resigned his position as superintendent of the American Smelting & Refining Co.'s plant at Maurer, N. J., to become vice-president and general manager of the Newton Manufacturing Co., Lowell, Mass.

Dr. **Joseph W. Richards**, on his way east from San Francisco, was the guest of the Lehigh Intermountain Alumni Association at luncheon on Sept. 27, at the University Club, Salt Lake City.

Mr. **Charles Sagert** has been made superintendent of the open-hearth steel plant of the Brier Hill Steel Co., Youngstown, Ohio, succeeding Edward Bailey, who has become connected with the Algoma Steel Co., at Sault Ste. Marie, Ontario.

Mr. **H. B. Zeller** has resigned his position as assistant superintendent of the coke plant of the Republic Iron & Steel Co., Youngstown, Ohio, to become superintendent of the new by-product plant of the Toledo Furnace Co., Toledo, Ohio.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, National Union Building, Washington, D. C.

Electroplating

AQUEOUS BATH, APPARATUS

28,590, June 5, 1860, John Matthews, Jr., of New York, N. Y.

Relates to coating the interior of lead and other tubing employed in mineral water apparatus, with silver. The tube itself is employed as the decomposition cell and cathode, a rod or wire passing longitudinally through the tube serving as anode. The tube is straightened, placed in a vertical position, and its lower end closed with a suitable rubber closure through which the anode wire passes. The anode is maintained in a central position by disks of rubber placed at suitable intervals along its length, and is arranged to be moved at will, longitudinally, in order to insure a uniform deposit on the tube. Any suitable silver-plating solution may be used.

75,258, March 10, 1868, Marshall L. Forbes, of West Meriden, Conn., assignor to the Meriden Britannia Company, of same place.

Relates to electroplating spoons and other articles, and to giving them deposits of metal of increased thickness at such places as are subjected to the greatest wear. This is accomplished by immersing different parts of the article to be plated for different periods of time. Two forms of apparatus are shown, each of which supports the spoon at its center, and permits tilting to immerse a gradually increasing surface of the spoon, giving a thick deposit at one point, gradually fading off to the part of the surface where there is little or no wear. After the spoon has received the desired partial coatings, it is removed from the holder and completely immersed, giving it a complete coating. Or the operation may be reversed, by first applying the complete coating, then the desired partial coatings.

78,497, June 2, 1868, William H. Watrous, of Hartford, Conn.

Relates to a frame for holding spoons, forks, etc., to be electroplated. The frame consists of a two-part clamp, one part pivoted to the other, and provided with a pair of jaws each having a serrated, or notched, edge, the notches in each opposite to each other, and co-operating to form a slot in which is suspended the spoon, etc., to be electroplated. The two parts of the clamp may be adjusted to each other by a screw, to admit different sized articles for plating. The complete clamp may hold a dozen or more spoons. The clamp is protected from contact with the electrolyte by a suitable non-conducting coating. The clamp and spoons are immersed in the electrolyte to a depth sufficient to entirely coat the spoons.

84,243, Nov. 17, 1868, Justin P. Woodworth, of Brooklyn, N. Y.

Relates to electrodepositing metals upon articles such as spoons, which are subjected to unequal wear, and to producing a thicker deposit upon the parts which are subjected to increased wear. A supporting rack having a number of holes or openings large enough to hold the spoon or other article to be plated is suspended within the plating tank. A narrow slot from the edge

of the rack to each hole or opening permits the insertion of the spoon. On each side of the rack, and facing the front and back of the spoons are supported deflecting plates of insulating material which shield the parts of the spoon that are not subjected to wear, but exposing to deposit the parts which are subjected to wear. These deflecting plates or shields are adjusted so that a heavy deposit is produced where desired, and a thin deposit where there is little or no wear.

108,510, Oct. 18, 1870, Dubois D. Parmelee, of New York, N. Y.

Relates to electroplating the interior of lead and other pipes. The pipe is first straightened, and then placed on a support at an angle of 20 or more degrees from the horizontal. An anode of the metal to be deposited is provided with several disks of insulating material, having serrated edges, to keep it central in the tube. Means are provided to gradually draw the anode through the pipe, so as to deposit a uniform coating throughout its length. The pipe may also be rotated, or turned slightly, if desired. The lower end of the pipe is closed by a plug, and filled with a suitable plating solution.

114,191, April 25, 1871, Dubois D. Parmelee, of New York, N. Y.

Refers to his earlier patent 108,510, upon which the present invention is an improvement. In this patent, the pipe to be coated is supported vertically, and a plurality of separate anodes are connected together and hung therein, like a chain, the entire length of the pipe. A drum above the pipe serves to support the anode, and to move it longitudinally from time to time to give a uniform deposit. The bottom of the pipe is connected to a reservoir of electrolyte which is pumped into the pipe, and returned when the deposit is completed.

128,166, June 18, 1872, Dubois D. Parmelee, of New York, N. Y.

Refers to his prior patents 108,510 and 114,191. The present patent is for the pipe coated by the apparatus described in the prior patents. It further refers to minor changes in the apparatus and method of use, for which the patent should be consulted.

148,409, March 10, 1874, William H. Bush, of New Haven, Conn.

A frame or flat box is provided with a metal top, perforated with many holes, and a screen or perforated plate within. The sides of the box are either removed, giving an open frame, or are perforated with large holes, to freely admit access to the electrolyte. Screws, tacks, rivets, etc., are inserted in the holes in the metal top, the ends or points thereof engaging the screen within. The screws are then placed in the usual cleaning solutions, then in the electroplating bath, after which the heads of the screws are suitably burnished while still in the frame.

148,409, March 10, 1874, William H. Bush, of New Haven, Conn.

Relates to a mechanism which regulates the quantity of deposit to be placed on an article. The apparatus consists of a counterbalance to one end of which is suspended the article to be plated. The balance is adjusted so that any predetermined weight of metal may be deposited, after which the lever tilts and closes a circuit which rings a bell announcing that the operation is completed, and at the same time operates a magnet which opens the plating circuit.

148,667, dated March 7, 1874, Evans Casselberry, of St. Louis, Mo., and Nathan H. Edgerton, of Philadelphia, Pa.

Consists of a receptacle through the bottom of which pass conductors to which are attached bifurcated wires or plates of platinum or other unoxidizable material. Water or other liquids in the receptacle are decomposed into their elements at the electrodes, the oxygen and hydrogen liberated is collected and may be used for fuel or other purposes.

Book Reviews

American Fertilizer Handbook. Eighth Annual Edition, 1915. Price, $1.00. Philadelphia: Ware Bros. Company.

The current edition of this useful handbook contains more complete statistics of the fertilizer industry than have previous editions. The usual directories of fertilizer manufacturers, allied fertilizer trades, cottonseed oil mills, and packers and renderers are included with special articles and complete fertilizer materials statistics. Among the special articles are the following: German and other sources of potash supply, by Charles H. MacDowell; the sulphuric acid industry, by Andrew M. Fairlie; use of concrete in fertilizer plants, by H. W. Latta; dictionary of fertilizer materials, by Thomas Coulson Pinkerton, five years of cyanamid in America, by E. J. Pranke.

* * *

Elektrochemie wasseriger Losungen.—(Electrochemistry of Aqueous Solutions), by Dr. Fritz Foerster, professor of the Institute of Technology of Dresden. Second enlarged and improved edition, 804 pages, with 186 illustrations. Price in paper cover, Marks 30; bound, Marks, 31.50 (retail price in New York, $10.50). Leipzig, 1915: Johann Ambrosius Barth.

This book is of the series of Applied Physical Chemistry Manuals edited by Prof. Dr. G. Bredig.

The first edition of Dr. Foerster's book appeared in 1905, and the decade's advance in both theoretical and applied electrochemistry has made the second edition necessary. While certain subjects are given more consideration than heretofore, the general plan is left unchanged. The author explains that it is, as before, a textbook which will point out primarily how the fundamental principles of electrochemistry are made useful by their application.

Conception of the broad field covered by the book may best be gained by listing its fifteen chapter titles, viz.: "Electrical Energy and Direct Current Electricity in General"; "The Law of Faraday and Its Practical Deductions"; "Theoretical Deductions from the Faraday Law, The Electrolytic Dissociation Theory"; "The Migration of Ions"; "Bath Voltage and Energy Efficiency"; "The Resistance of Electrolytes"; "Electrical Osmosis"; "The Production of Electrical Energy in Galvanic Elements"; General Theories of Electrolysis"; "Electrolytic Evolution of Hydrogen and Oxygen"; "Special Electrochemistry of Metals"; "Application of Electrochemistry to the Metals"; "Electrolytic Reduction"; "Special Electrochemistry of the Halogens"; "Electrolytic Oxidation." Author and subject indices are included, as well as references to all original articles.

The chapter on the application of electrochemistry to the metals is very comprehensive. It treats with all the important metals, giving greatest space to copper and its refining. The 150 pages devoted to the electrochemistry of the Halogens include both the theoretical and applied branches of this important division of the science.

Dr. Foerster is widely known by his contributions to scientific literature and his most recent edition is a reliable and useful standard reference book for all those interested in the applications of the electrochemistry of aqueous solutions.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, NOVEMBER 1, 1915 No. 13

Published Semi-monthly on the First and Fifteenth of Each Month by the

McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.
A. E. Clifford, Secretary. John T. DeMott, Treasurer

239 West 39th St., New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Col.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for November 1, 1915

EDITORIAL:

Artificial Indigo Made in the United States..... 773
Electrolytic Zinc 774
Bessemer Steel 774
Riffling Concentration Tables 775
A "Steel Famine" Possible 775
American Indigo Industry..... 776
Niagara Falls Section American Electrochemical Society (Transformers for Electric Furnace Work)..... 776
The Iron and Steel Market..... 776
Metallurgical and Chemical Engineering in Great Britain.... 778
The Dyestuff Situation—Papers and Discussion Before the New York Section of the Society of Chemical Industry.... 779
Coming Society Meetings 782
The School of Chemistry of the University of Pittsburgh..... 782
Zinc Oxide from Lead Blast Furnace Slag, as in Operation at South Chicago. By H. B. Pulsifer..... 783
Removing Iron Scale by Pickling; Theory vs. Practice. By Carl Hering 785
A Rapid Precise Standardization of Acid Solutions. By Merle Randall and Charles C. Scalione..... 787
Thermal Principles of the Blast Furnace. By J. E. Johnson, Jr. 787
A New Electrolytic Method of Sewage Disposal. By J. C. Olsen 793
The Chemical Engineering of the Hardwood Distillation Industry. By James R. Withrow..... 797
More Engineering English 799
The Relation of Chemistry and Mechanical Manipulation to the Evolution of the Glass Industry. By Robert L. Frink.. 800
Inflammability of Mixtures of Gasoline-Vapor and Air..... 802
The Electrolytic Precipitation of Gold, Silver and Copper from Cyanide Solutions. By G. H. Clevenger..... 803
Paint. By G. B. Heckel..... 806
Synopsis of Recent Chemical and Metallurgical Literature 811
Recent Chemical and Metallurgical Patents..... 815
Conveyor Belt Calculating Chart..... 818
New Portable Direct-Current and Alternating-Current Electrodynamometer Instruments 819
New Riffling for Concentrating Tables..... 819
Personal 820
Digest of Electrochemical U. S. Patents..... 821
Book Reviews 822

Artificial Indigo Made in the United States

The announcement on page 776 of this issue to the effect that the Dow Chemical Company of Midland, Mich., is erecting an artificial indigo plant of a daily capacity of 5000 lb. of 20 per cent indigo paste, will be welcome news to all who, at the recent Exposition of Chemical Industries in New York City, looked at the first sample of artificial indigo made by this company. Mr. H. H. Dow has been an enterprising and courageous pioneer of industrial chemistry in America in many ways. His electrolytic work on a large scale has been of considerable originality and very successful. In transplanting the manufacture of artificial indigo—one of the greatest triumphs of German chemistry—to American soil, Mr. Dow is setting a new milestone in the development of the American dyestuff industry and deserves the heartiest good wishes for the success of his enterprise and pluck.

It still takes a very plucky man to erect a new dyestuff plant in this country. This will be evident from the report on page 779 of the meeting held last week on the dyestuff situation by the New York Section of the Society of Chemical Industry. It was a lively and enthusiastic meeting and there was unanimity of opinion that this country should and must have a dyestuff industry able to fill the needs of the country. But there was anything but unanimity of opinion as to the best way to go about it. Free expression of contrary opinions is always beneficial; and contrary opinions of all shades were expressed from the socialistic demand for a Government factory for the production of the intermediates as one extreme to the individualistic laissez-faire doctrine on the other hand that "the dumping clause is all nonsense; the textile man has a right to buy at the lowest price; everything else is theory and bunk."

This country has two prerequisite elements for the success of a large dyestuff industry—the raw materials and the market. Further a sufficient supply of chemists and chemical engineers—the intellectual raw materials of the industry—will be available in time and in time the technical skill will be acquired which comes only from long years of practice. But it would be foolish to overlook that this will take years of hard work, especially as the dyestuff industry does not lend itself to mass production. During this period of evolution the growing American dyestuff industry will need protection by the government. On this everybody in the meeting last week agreed. But while the whole chemical industry is unanimous in its conviction of the absolute necessity of a protective *tariff*, besides an anti-dumping clause, the representatives of the government shirked *tariff* discussion. Dr. E. E. Pratt, in his other-

wise excellent and very able address, thought that the tariff question is of less importance and can be left out of the discussion, as "we are not likely to reach any final conclusion in such a discussion." This may have been politically expedient, but to us it was the most disappointing note in the whole evening's discussion. Will even those government officials who are most intimately connected with the chemical industry, overlook the obvious fact to which we emphatically called attention at this place last week, namely, that the American chemical industries face a condition, not a theory, and that the abstract question of the desirability or undesirability of protective tariffs has nothing to do with the special concrete situation with which the chemical industry of this country and all who depend on it are now confronted?

Electrolytic Zinc

The production of electrolytic zinc is engaging the serious attention of an increasing number of leading metallurgical concerns, with a fair prospect of developing methods that will practically solve some unusual problems in ore treatment. This impetus to zinc hydrometallurgy with electrolytic recovery arises mainly from the necessity of devising wholly new or improved methods of treating silver-bearing zinc ores and certain complex zinc sulphide ores which are not amenable to ore dressing. Further, the prospect of high prices for spelter makes the present a peculiarly favorable time to embark in new enterprises of this sort.

At Trail, B. C., the Consolidated company is investigating the production of electrolytic zinc from a zinc-lead ore which contains the sulphides of those metals intimately associated in finely crystalline form. Mechanical methods of separation and enrichment are not applicable, and chemical means must be employed. At Anaconda an experimental plant for electrolytic zinc is in operation on certain silver-bearing Montana zinc ores. Near Salt Lake City and San Francisco further work is under way with electrolytic zinc as the goal, and encouraging experimental results are reported.

If the outcome at any one of these places gives the solution of a special problem in zinc metallurgy, a useful and economic purpose will have been served, and the way may be paved to an extension of the process. As has frequently been observed, it is unlikely that the present art of zinc smelting will be revolutionized by these special processes, but there is always the prospect that changing economic conditions will make it possible to widen a field which at first appeared narrow. Prophecy is always hazardous, but particularly so when it attempts to forecast what cannot and never will be accomplished. Electrolytic zinc may still become a case in point.

Bessemer Steel

The place that Bessemer steel now occupies in the steel-consuming industries is one that has been made by fortuitous circumstances rather than by design, and the place is not as important as it might be. This is unfortunate now, for a famine is threatened in steel, and the famine would be reduced in intensity if Bessemer steel were more generally used. The metallurgist has confined himself almost exclusively to open-hearth steel, his effort being to improve open-hearth steel rather than Bessemer. He might have done differently if he had not been restricted in the matter of phosphorus. There is, and has been for many years in the United States, practically but one phosphorus content, and that is a content that will just pass muster as being not over 0.10 per cent. It is curious in the retrospect to reflect that the influence that caused the rapid erection of basic open-hearth furnaces in recent years was the same influence that caused the phosphorus to be fixed at as close to 0.10 per cent as possible, that influence being fear of a shortage of Bessemer ores. The metallurgists have not been allowed to consider what might be done with a Bessemer steel of 0.06 or 0.08 phosphorus content. There are ores that will make such steel, but established custom is to mix them with ores of higher phosphorus content, so as to produce a steel just within the established limit. The custom has been established for years, but it is justifiable at this time to raise a question whether it has not outlived its usefulness.

The distinctively bad feature of commercial Bessemer steel is its low shock ductility in proportion to its static ductility, a characteristic usually attributed to its phosphorus content. This difference between static and shock ductility, established by the engineers, has become generally recognized in the commercial use of steel, whether or not the users themselves know the meaning of the terms static and shock ductility, for one finds the widest use of Bessemer steel to-day in the manufacture of wire, tin plate and steel pipe, all commodities which are relatively little subject to shock in actual use.

Apart from modifications that might be made in the composition of Bessemer steel by a less rigid conservation of the relatively low phosphorus ores, a more widespread use of Bessemer steel might perhaps be cultivated by a judicious educational campaign. For instance, phosphorus tends to produce coarse crystallization, and the temperature to which the steel should be heated in rolling is correspondingly limited. Black plate for tinning is rolled in packs, and to prevent scaling of the tin plate bar and sticking in the pack, which would result in surface imperfections, the rolling is conducted at a lower temperature than any other hot rolling operation. It is a fortuitous circumstance that the practice conduces to bringing out the best physical qualities of Bessemer steel, yet it will hardly be denied that it does do so, and more attention paid to rolling temperatures in other classes of mills might result in a distinct gain.

There has been little disposition in the steel-making trade to encourage the use of Bessemer steel because commercial conditions have not favored the effort. When the demand for steel is small, the producers who can furnish either open-hearth or Bessemer gladly furnish the former, for as a rule they can make it somewhat more cheaply, and every cent per ton counts in such times. When the demand for steel is excessive the buyer is expected simply to take what he can get, to select rela-

tively prompt delivery of Bessemer steel in preference to later delivery of open-hearth steel, if the earlier delivery will suit his purpose better. Thus the position of Bessemer steel, while apparently open to criticism from the technical standpoint, is regarded as defensible from the commercial standpoint.

Riffling Concentration Tables

The present method of riffling concentration tables has not varied greatly from that which was early adopted and found practicable. Such changes as have been made have been conservative, and until recently practice seemed to have become standardized, with little thought of departure from existing custom. We may draw two inferences—either we have reached the ultimate in riffling, or else standardization has acted as a bar to progress by creating the impression that there is nothing to be gained by leaving the beaten trail.

Generally speaking, it seems probable that standardization has been more complete and has been accepted with less question in the case of riffling than in other factors in ore treatment. The same type of riffling has been used with a great variety of ores and under widely different conditions. In this respect we have acted at variance with an accepted principle; viz., that each ore presents an individual problem requiring special study to provide the most efficient method of treatment. Have we given sufficient study to the development of special forms of riffling for different ores, to the end that the best results in concentration may be secured? We think not. As a rule the standard forms of riffling have been adopted without question and often without experiment, while considerable study has been given to other features of the process to be employed.

Considering the diverse conditions existing in concentratable ores, a study of the effect of variations in riffling seems to offer a fruitful field for investigation. One who has engaged in this line of research has obtained results that are surprising, leading to the broad conclusion that, for a given ore, experiment may reveal a method of riffling that will prove more effective than the standard forms. In a number of cases wherein ordinary types of riffling have been ineffective, the results have been remarkably improved by varying the depth, spacing or arrangement of the cleats on the deck. The point seems worthy of more attention than it has received in ore testing.

A "Steel Famine" Possible

The pressure upon the steel mills for steel has reached a tense stage. Buyers are clamoring to place orders and contracts, while the mills are unprecedently reserved in the making of commitments. In October, 1912, when the buying movement of that year reached its height, the increase in the United States Steel Corporation's unfilled obligations was more than a million tons. No such monthly increases are permitted now.

The insistence of the demand for steel is proved quite conclusively by a comparison of the course of prices in this movement and the course in the last movement. In the past decade there have been three major movements in the steel market, that of 1905-6-7, that of 1909 and that of 1912. Steel prices have advanced steadily from the beginning of the year to the present time. The low point of last December was a shade below the low point that preceded the 1912 rise. Present prices for finished steel products are now at an average level with the top prices reached in the 1912 movement, and they are now advancing at a more rapid rate than at any previous time in this movement, a conclusive evidence that the movement is a much stronger one than its predecessor.

To what extent the production of steel can be increased is problematical. The pressure is distinctly upon the steel-producing units, not upon the blast furnaces nor upon steel-rolling departments. To increase the production of steel it would not be necessary to build from the ore mine to the finished product. The relation between steel-producing capacity and blast furnace and steel-rolling capacity, however, is an abnormal one, because an important proportion of the present steel output is of shell steel, involving a heavy discard from the ingot, and thus the proportion of steel rolled to steel poured is abnormally low, and this low proportion is to be simply concurrent with the duration of the war. A not unimportant fact is that the production of steel in the next three months may be less than in the past three months, on account of unfavorable weather conditions.

The United States has about 45 per cent of the pig iron making capacity of the world, and approximately the same proportion of the steel-making capacity. Six months ago the proportion would probably have been estimated at nearer 40 per cent, but the performance of American blast furnaces in the past few months, many of them, if not the majority, breaking all their previous records, though with no change in the physical equipment, indicates that the total capacity of the United States is two or three million tons a year greater than was estimated before this recent test.

All the other iron-producing countries of the least importance are engaged in the war. As a group their exports of iron and steel to non-producing countries are very greatly reduced, and the non-producing countries, recovered in some part at least from the financial shock produced at the outbreak of the war, and with the stocks of material they were carrying greatly reduced if not entirely exhausted, are calling for much more material from the United States. The entente allies, although as a group large producers of iron and steel, are calling upon the United States for enormous tonnages of material in various stages of manufacture.

Business in the United States has been rapidly reviving, with further expansion promised. Productive capacity in the iron and steel industry has grown much less rapidly since 1909, when the great construction program the industry had assumed in 1906 and 1907 was finished, than it did in earlier years, and altogether it is not surprising that a famine in steel should now be threatened.

American Indigo Industry

The Dow Chemical Company of Midland, Mich., is erecting an artificial indigo plant with a capacity of producing 5000 lbs of ordinary indigo paste daily.

As mentioned in our report of the First National Exposition of Chemical Industries, held in New York City in September, a sample of artificial indigo was then exhibited. It may now be stated that this had been produced by the Dow Chemical Company which had a miniature factory for the production of indigo in successful operation for several months.

It is interesting to note in this connection that there are 39 research chemists on the staff of the Dow Chemical Company. They are working in nine different laboratories.

Niagara Falls Section American Electrochemical Society

Transformers for Electric Furnace Work

(*From Our Special Correspondent*)

An air of unnatural solemnity overhung the meeting of the Niagara Falls Section of the A. E. S. at the Niagara Falls Power Co. on Oct. 12. Whether this was due to the fact that some of the liveliest members were engaged elsewhere in electioneering; whether to the whispered tones employed by most of the speakers, apparently awed by the solemnity of a "first meeting"; whether to the fact that the president had secured more material than he could comfortably work off in a reasonable time and consequently was unable to employ his favorite tactics of stirring things up, the fact remains that there were no casualties.

L. E. Imlay opened the proceedings by directing the attention of the audience to the useful subject of reactance in transformers, external and internal, and described, with diagrams, its effect in protection and its effect on regulation. W. S. Horry, who followed, refused to be bound by any narrow regard for the subject of the evening; he preferred to warn the section of the importance of starting its life with a proper conception of its duties and its limits; "from the Niagara River to the secondary we meet on common ground," he stated, and broadly hinted that beyond the secondary were mysteries into which it would be, to say the least, tactless to inquire. After defining a transformer as something which was bound to be frightfully overloaded in the course of its life, he stated that he did not see that anything more could be asked than that shop tests should show that specifications had been complied with, though, he added, as an afterthought, that provision against breakdowns was, of course, paramount. That this paramount condition is not always fulfilled was the burden of the next three speakers, who told harrowing stories of their experiences in recent years. These pictures were, however, not without lighter relief, as when F. J. Tone celebrated Columbus Day by describing how Paul Lincoln and F. A. J. FitzGerald discovered power factor in the early days of the Carborundum company. A. M. Williamson gave a psychological study of the effect on an operating superintendent of the information that "number one unit is on the bum and due for a ride on the flat car," but paid a tribute to the increased efficiency of the repair department of the transformer company by contrasting the 175 days necessary for the repair of the first unit with the most recent record of forty-five on the fourth; the curve was apparently logarithmic, and indicated an approach to 100 per cent efficiency in 1926. F. A. Lidbury sighed for the old days of 2200-volt primary operation, and described some highly unconventional surgery performed on an old transformer built in 1897, for which he evidently had a great affection. F. A. J. FitzGerald described some experiments made by simultaneously observing the temperature of oil in transformers and the temperature of the coils themselves by the "thermoscope," and drew the conclusion "that transformers which are apt to be overheated should be supplied with devices that will let the operators know when the coils are at a dangerous temperature instead of the thermometer in the oil, for this is worse than useless, giving as it does a false sense of security."

Mr. McConahey of Pittsburgh followed with an interesting description of problems in transformer design and manufacture, and showed a large number of lantern slides chiefly illustrating methods of bracing. He prefaced this exhibition by the remark that he was going to let us into a few transformer secrets, that "we electrical engineers are not like you electrochemical men—we don't keep everything we know under our hats." After this wild horses could not drag from us what he said.

John J. Frank of Pittsfield followed, and he really tried to start something. "When you are in trouble, call upon someone who may know more about it than you do," he began, and left little doubt in the minds of his audience whom he meant; after this, however, we were scarcely prepared for his admission that "twenty years ago we didn't know as much about transformers as we do to-day." Acting upon the Billy Sunday principle, that the easiest way to become popular with your audience is to abuse them, he proceeded to draw up a frightful indictment of electric furnace men. According to the speaker, they habitually overloaded transformers 500 per cent; and "when a piece of apparatus is rated 1000 kw. and you take 5000 out of it for years something must happen." Worse still, short-circuiting transformers was one of their favorite amusements, and they were further guilty of hiding from the innocent transformer manufacturer all manner of frightful conditions, high frequencies, rectification phenomena, and so on. Of course, this roused the president's ire at once, as it was intended to do, and there might have developed a certain liveliness had not Mr. Greene, also of Pittsfield, who followed, thrown oil on the troubled waters by admitting that transformer designers owed much of what they to-day know to the co-operation of users of transformers, and particularly to electric furnace men. According to Mr. Greene, the manufacturer now knows how to build to withstand short-circuit and voltage stresses, and on this assumption the most important question is now that of voltage regulation. The induction regulator, while most satisfactory, is too costly, therefore control by taps and dial switches, with intermediate arrangements where necessary, is now being resorted to. He outlined the tendencies in construction along these lines at the present day.

After some discussion as to the respective merits of internal and external reactance, and the amount of reactance for various conditions, in which F. J. Marshall, A. J. Jones, R. H. White and C. A. Winder participated, the meeting adjourned.

The Iron and Steel Market

Steel buyers have become much more insistent in the past fortnight, while steel producers have become still more reserved in the matter of making contracts for forward delivery, resulting in a tense situation, with prices tending to advance more rapidly than at any previous time in this upward movement, now ten months old. Effective Oct. 25, the Carnegie Steel Company advanced bars, plates and shapes $1 a ton, to 1.50c.,

this price at once becoming the minimum of the market. The company's previous advance was dated only ten days earlier, while the preceding advance had been about a fortnight earlier, making a total advance in these products of $3 a ton in less than thirty days. With their related products of skelp, hoops, bands, etc., these products comprise fully one-half the total rolled-steel product of the industry, excluding standard rails, which may properly be excluded in such a comparison as they have not changed definitely in price in more than fourteen years.

The average price of all finished steel products is now equal to the average in the winter of 1912-13, when the great advance of 1912 had culminated and the market was preparing for a period of decline. Prices are still about $2 a ton below the highest level reached in the 1909 rise, and about $6 a ton below the level of 1907. It would be quite unsafe to venture a prediction that the records of 1909 and 1907 would not be broken even in a very few months, so strong is the present price advancing tendency.

The physical influences in the steel market are very strong. Mills have been falling farther and farther behind in deliveries, although in the past three months they have not only produced steel at a much greater rate than ever before, but have doubtless attained the maximum output of which they are capable. Consumptive demand by domestic industries generally is increasing, while the railroads are facing a car shortage not merely during the crop-moving season but thereafter, while their net earnings are at a new high record. The demand from certain belligerent countries is extremely heavy, with no signs of abatement, and the demand from neutral countries is constantly increasing.

The mental influences in the steel market are equally strong, in the matter of tending to advance prices. Buyers of steel are familiar with the fact that war tends to raise prices and recognize that the demand for steel is unprecedented, so that they are much less disposed to resist advances than is usually the case. Sellers are distinctly governed by a different policy than formerly. The theory that steady prices for steel mean steady demand has not worked out satisfactorily. Having passed through a long and severe depression, steel producers are committed to a policy of securing returns when returns can be secured, and the demand with which they are confronted is in the main not such as would be curtailed by price advances to the extent that might be expected under normal conditions. It is a patent fact that conditions in the world are very far from normal.

Thus both physical and mental influences combine to give a strongly advancing trend to steel prices. The end is by no means in sight, and it is easy to imagine prices advancing much more in the next ten months, possibly in the next six months, than they have advanced in the past ten.

Connellsville Coke

An outstanding feature of the general course of prices in the iron and steel industry during the first nine months of the year was that Connellsville coke failed to score any material advance, whereas in previous price movement in the industry coke advanced much more in percentage than did pig iron or steel. The reason was that the rapid erection of by-product coke ovens in recent years produced a total coke-making capacity much in excess of the possible requirements of blast furnaces. Late in September, however, the strength in the general situation became so great that furnaces began to inquire for coke for 1916 delivery, against the expiration of contracts at the close of this year, and in succeeding weeks, up to the middle of October, the major portion of the contract business was done at prices averaging about $2.25 per net ton at ovens, an advance of perhaps 50 cents a ton over contract prices for the present half-year. Furnace coke for prompt shipment remained at a relatively low price. The middle of October found prompt furnace coke at $1.75 to $1.85, and then prices jumped suddenly until within a few days as high as $2.75 was paid for coke for spot shipment. The production of the Connellsville region expanded until a point was reached at which labor scarcity intervened. It remains a question whether the scarcity of coke for prompt shipment will be relieved, or the contract price for next year will advance to the level of the prompt market.

Pig Iron

After the fairly sharp advances that characterized the pig-iron market in July, August and September, a distinct lull occurred in buying, and prices were stationary for practically the first three weeks in October, when a fresh advancing movement began, based not so much upon an increase in buying as upon sentiment, as steel prices were rising rapidly and a broader market for pig iron seemed in prospect. In the past fortnight Southern iron has advanced 50 cents a ton, while the Chicago furnaces marked up prices by no less than $1.50 and foundry iron in the valleys advanced 50 cents, to a level with the previously established market for basic iron, a level to which it was entitled by reference to cost of production. The steel mills do not buy merchant pig iron to the extent usually expected when they are crowding for production, but predictions are made that consumption by iron foundries is destined to increase materially. The market is quotable as follows: No. 2 foundry, delivered Philadelphia, $16.25 to $16.75; f.o.b. furnace, Buffalo, $15.50 to $16; delivered Cleveland, $15.25; f.o.b. furnace, Chicago, $15.50 to $16; f.o.b. Birmingham, $12 for prompt and $13 for first half delivery; at valley furnaces, 95 cents higher delivered Pittsburgh: Bessemer, $16; basic, malleable and foundry, $15; gray forge, $14.50.

The Jones & Laughlin Steel Company has leased Rebecca, a merchant stack at Kittanning, Pa., and will manufacture its ferromanganese at that furnace, thus releasing one of the stacks at its Aliquippa works for the production of standard basic. Rebecca was idle, but plans had been completed by the owners for blowing it in on basic iron for the market.

Steel

Soft steel billets have not been really a market commodity of late. The mills were oversold for early deliveries and did not care to make commitments for late delivery. Nominally the market has been called $25 for Bessemer and $26 for open-hearth billets, with $1 extra for sheet bars, but practically there have been no sellers. Transactions for 1916 delivery are just beginning. A sale of 4500 tons of open-hearth sheet bars for delivery January to June has been made at slightly over $30 delivered, equivalent to about $28 at maker's mill, Pittsburgh, and Bessemer sheet bars are reported to have been sold for first quarters at about $27, Pittsburgh. Makers of large rounds for shells, possibly caught short, have paid all the way from $50 to $70 for billets made to shell steel specifications, discards 25 or 30 per cent, ingots chipped, and analysis fairly stringent though by no means difficult. Rods are $32 to $33, Pittsburgh.

Finished Steel

Effective Oct. 21 wire products were advanced $2 a ton. Bars, plates and shapes advanced $1 a ton about Oct. 25. Black and blue annealed sheets have advanced rather steadily. Tubular goods are unchanged.

Current quotations, f.o.b. Pittsburgh, unless otherwise noted, and in general for delivery at mill convenience, with premiums sometimes paid for prompt shipment, and with forward contracts difficult to place:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.50c.

Shapes, 1.50c.

Steel bars and bands, 1.50c., base; steel hoops, 1.70c. to 1.75c.

Iron bars, 1.559c. to 1.609c., Philadelphia; 1.35c., Chicago; 1.45c. to 1.50c., Pittsburgh.

Plain wire, 1.70c.; wire nails, $1.85 per keg, base; painted barb wire, 2.00c.; galvanized barb wire, 2.70c.; fabricated wire fence, 69½ per cent off list, in carload lots.

Sheets, blue annealed, 10-gage, 1.70c.; black, 28-gage, 2.10c. to 2.20c.; galvanized, 28-gage, 3.50c. to 3.60c.; painted corrugated, 28-gage, 2.30c.; galvanized corrugated, 28-gage, 3.55c. to 3.65c.

Tin plate, $3.10 to $3.20 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 63½ per cent off list.

Boiler tubes (less than carloads), 3½ to 4½-in., 71 per cent off list.

Structural rivets, 1.90c.; boiler rivets, 2.00c.

Notes on Chemistry and Metallurgy in Great Britain

(From our London Correspondent)

The Organization of Scientific and Industrial Research

We are a strange race. A national research scheme has been established. It was needed badly enough. But the net result is a ruling authority of successful politicians advised by ultra-scientific figure-heads.

There is first of all the establishment of a Committee of the Privy Council responsible for the expenditure of any new money provided by Parliament. This comprises the Lord President, the Chancellor of the Exchequer, the Secretary of State for Scotland, the President of the Board of Education, the Chief Secretary for Ireland, "together with such other Ministers and individual members of the Privy Council as it may be thought desirable to add." Under this category Lord Haldane, Mr. Arthur Acland, and Mr. J. A. Pease have been added to the Committee.

The second link in the chain is the advisory council which has to advise the Committee on:

(1) Proposals for instituting scientific research.

(2) Proposals for establishing or developing special institutions or departments of existing institutions for the scientific study of problems affecting particular industries and trades.

(3) The establishment and award of Research Studentships and Fellowships.

The first members of the advisory council are Lord Rayleigh, Dr. G. T. Beilby, Mr. W. Duddell, Prof. B. Hopkinson, Professor McLelland, Professor Meldola, Professor Threlfall, and Sir William M'Cormick. Of course Mr. Duddell, and to a certain extent Mr. Beilby, are open to suspicion as having some practical experience of applied science, but so far as the advisory council is concerned there is no direct representative of manufacturing interests. As for the Committee of the Privy Council and hope of representation of manufacturing interests by men who know depends on the fortuitous chances and mischances of who may be the members of H. M. Government at any given moment. There is in fact no prospect that the men who know will under the present scheme ever sit on the ultimate court of administration.

Yet despite these defects which your correspondent voices and which are very widely recognized, the scheme is by no means doomed. Salvation will be with the practical scientists on the Institutional Research Committees and in the sub-committees they appoint to deal with specific subjects. In spite of all the very learned or politically very successful figure-heads, in spite of all this top hamper one can still hope for good results. It is another question whether the over-all efficiency will not be capable of great improvement. In England figure-heads are necessary, and one supposes that it is only as a sop to the modern democratic unrest that they are not at once more numerous and more picturesque, and more uselessly arundite. According to all precedent there should at least have been added a spiritual peer, an eminent Assyriologist, a titled philatelist, the Astronomer Royal, and the President of the divorce court.

The Lighting of Factories and Workshops

The first report of the Home Office Departmental Committee on lighting in factories and workshops has just been issued, the Committee feeling that although the investigation is incomplete, and cannot be completed under the conditions prevailing at present, it is desirable to make available to the public the work already done, and to formulate certain recommendations regarding suitable standards of illumination. The report contains an immense amount of detailed information, and the subject is discussed at considerable length. The conclusions of the Committee in brief are that statutory standards of "adequate and suitable illumination" should be set up, and the standards suggested are minimum illumination on a horizontal plane at the floor level of 0.25 foot-candle in workrooms, 0.4 foot-candle in foundries, 0.1 foot-candle in passages, and 0.05 foot-candle in open spaces out of doors. These recommendations are subject to certain qualifications and exemptions, and are, of course, only provisional; they will serve, however, to indicate approximately the standards that will eventually be adopted, and will thus be of assistance to works managers, who will also find the mass of data contained in the voluminous appendices of the greatest value.

Market Prices

AUGUST, 1915.

Copper opened (3d) £72.10 and was £74 on the 4th, then fell away to £66.17.6 on the 13th. It subsequently improved a little to £67.17.6 on the 16th, but afterward continued to fall to £64.7.6 on the 23d. On the 25th a sharp rise of £3 occurred, and on the 26th £72.15 was reached, and £72.17.6 on the 27th. It closes lower at £68.17.6.

Tin opened £156.15 and dropped away to £150 by the 9th, and, after touching £152.6 on the 11th, to £149.10 on the 13th. It then hardened slightly but was again falling on the 18th and reached £148.5 on the 20th. On the 24th it was £150.5. This metal also participated in the rise on the 25th, and was £153 on the 27th, closing at £151.5.

Cleveland opened 65/10½ and touched 66/3 on the 5th and 66/4½ on the 9th and 11th, but afterward went lower, declining to 64/1½ by the 20th. On the 23d it was 64/7 and closed 65/6.

Hematite remained at 95/- throughout the month.

Scotch Pig opened 71/10½ and was 72/4½ by the 9th and on the 11th, but 71/10½ on the 13th and 70/31½ on the 20th. On the 24th it had recovered to 71/1½ but closed 70/9.

English Lead opened £24.15 and fell steadily to £21.10 on the 12th, recovering then to £22 and on the 24th to £22.10, closing same price.

The Dyestuff Situation—Papers and Discussion

Before the New York Section of Society of Chemical Industry

With the largest attendance which has ever occupied Rumford Hall, in the Chemists Club, the New York Section of the Society of Chemical Industry held a meeting on the evening of Oct. 22 for the presentation of papers and discussion on the dyestuff situation in this country. It is estimated that between 400 and 500 were present. Every available space was taken and many were forced to stand throughout the meeting, showing the live interest which is taken in this question. The chairman of the section, Dr. **William M. Grosvenor,** in opening the meeting said that regular business would be dispensed with and then gave over the conduction of the meeting to Dr. **Charles F. Chandler.**

Dr. Chandler gave a very interesting talk, showing the tremendous advantage which Germany has over America in making dyes in view of her many years of valuable experience and wonderful commercial development. In reviewing the discovery of dyes he said that Wolf in 1771 was the first to make an artificial organic dye. He treated natural indigo with nitric acid, forming picric acid. However, the epoch-making invention was Perkin's mauve (1856) and the present dyestuff industry really dates from that time. Dr. Chandler, who had visited many of the largest German factories, spoke of the wonderful and intricate development which has taken place in their dye industry. Friedrich Bayer & Company of Elberfeld, had in 1875 eleven chemists. In 1905 they had 300 doctors of philosophy—university graduates—and 8000 workmen. Is it any wonder that they can make dyes with this co-operation between university and factory? This company exhibited 161 colors at the Centennial Exposition in 1876. Not long ago they bought a square mile of land for additions to their factory. One of the newspapers recently gave an account of a plant under contemplation which was to make dyes in Long Island City. This plant was to be 40 ft. by 75 ft. A splendid account of the development of the coal tar industry is that by Friedlaender comprising thirteen volumes and describing the industry from 1877 to 1912. We ought to prevail upon our own Government that the Bureau of Census bring up to date and re-issue the catalog of U. S. chemical patents published in 1902. This would be a very valuable reference work.

DR. CHANDLER: *Hall's process for cracking gas oil—three plants in Europe of a total daily capacity of 21,000 gal. gasoline.*

In concluding Dr. Chandler eulogized the splendid work of the American WM. A. HALL in the cracking of petroleum (U. S. Pat. 24,491, 1913), and gave out some facts of history so far not published. In 1913 Hall put up a small plant at Greenpoint and Dr. Chandler was asked to pass expert opinion on the process and product. Hall started out from gas oil, which at that time was 3½ to 4 cents per gallon. Upon cracking this, 10 per cent gaseous and 90 per cent liquid products were obtained; of the latter 55.76 per cent consisted of "motor spirits," or gasoline. Later improvements, such as a second treatment, brought the yield of motor spirits well over 70 gal. per 100 gal. of gas oil. By actual tests it was found that an automobile required less Hall gasoline than that of the standard. For example, at 1600 r.p.m. 18 per cent more of the standard gasoline was consumed, and at 1200 r.p.m. 31 per cent more.

However, Hall found great difficulty in interesting capital in this country in 1913, and accordingly took his process to England. There he succeeded in obtaining funds and set up a plant with an output of 6000 gal. of motor spirits per day, besides valuable by-products, such as benzol (about 6 gal. per 100 of gas oil) and toluol (about 10 gal.).

During the last year the English Government assisted in the erection of a second 6000-gal. plant, and both plants are now working night and day. A third plant of 9000 gal. has been erected in Continental Europe.

Dr. Chandler then introduced the first speaker on the program, Dr. **E. E. Pratt,** chief of the Bureau of Foreign and Domestic Commerce, Washington, D. C.

Dr. **Pratt** presented a very able paper on "Do We Want a Coal-Tar Industry?" He first reviewed the German industry, giving statistics of capitalization and production. Of the world's production, valued at $92,150,000, Germany produced $68,300,000, or 74 per cent of the world's supply. Three factors are to be taken into consideration in discussing the American dyestuff industry, viz., raw materials, markets and technical skill. The United States has five times the coal supply of Europe, consequently this raw material is well taken care of. The market is about $15,000,000 annually. In technical skill we are not so well equipped, but this has been because of the lack of demand. Our schools can turn out all the chemists needed.

DR. PRATT: *Do we want a dyestuff industry? If so, it must be protected. What protection is necessary?*

Dr. Pratt reviewed the attempts of American manufacturers to make dyes since the first factory was started in Buffalo in 1879. He showed how the foreign interests had undersold American manufacturers at rates below market prices in order to drive them out of business. He quoted from a letter of the Benzol Products Company to the Commissioner of Corporations under date of Jan. 2, 1915, showing the relentless endeavors of the European interests to drive this concern out of business. At one time they lowered the price of aniline oil to such an extent that a price of 8.5 cents failed to secure the order for the American company when the regular market price was 10.9 cents per pound. In 1912 a British member of the European convention tried to induce the Benzol Products Company to go out of business, offering to sell them aniline oil so they could still make a profit on their contracts. "Such unfair methods as these must in some way be prevented. The total loss, direct and indirect, now being borne by American users of dyestuffs and dye wares amounts to not less than $1,000,000 per day. Our users of colors have reverted to dyestuffs and methods long since obsolete and almost forgotten.

"Since the outbreak of the war the five domestic concerns manufacturing dyestuffs have doubled their outputs. One new plant is now in existence and is producing 1000 lb. daily. Another plant will be ready for operation about Nov. 1, and still another capitalized at $15,000,000 has started plans for extensive works. We are making progress but there is a long way to go."

A report is now being prepared by Dr. Thos. H. Norton showing exactly the amount of each of the artificial dyestuffs now in current use in this country consumed by our various textile and other industries during the fiscal year 1914. Such a census of the dyestuffs has never been attempted before and should be a great help in establishing our industry.

"The most powerful weapon, however, in the hands of the foreign manufacturer is the power to throw out of gear our enormous textile industries and all dependent interests during the period inevitably necessary to create an American coal-tar industry. Recommendation will be made by the Department of Commerce that Congress, in whose hands this matter ultimately rests, shall pass such legislation as will, beyond the peradventure of a doubt, furnish the necessary protection. The experience of Canada, South Africa and Australia in this matter should be of great assistance. These countries have passed laws protecting their home industries. Dr. Pratt did not think the tariff question was of such importance as to warrant its discussion, as no final conclusion in that matter would likely be reached, and other means are at present of more importance.

The next paper was presented by Mr. **J. F. Schoellkopf** of Schoellkopf, Hartford & Hanna Co., Buffalo, N. Y., who have been manufacturing since 1879. He spoke on "The Aniline Industry from a Manufacturer's Viewpoint." He emphasized the fact that to be made economically, a great variety and a flexibility of machinery and equipment was necessary. The annual consumption of dyes is estimated at 40 million pounds. Probably close to 1000 different colors are used and no two are made exactly the same. About one dozen colors constitute 75 per cent of the production. The European factories have a larger producton than ours and can consequently run cheaper. The Farbwerke-Hoechst has 300 chemists, 100 of which are analytical and the other 200 have charge of the manufacture of about 500 colors, so that one chemist has only two or three colors under his direct supervision. Here in America people expect one or two chemists to control the manufacture of a thousand dyes and insist upon automatic processes of manufacture. It is absolutely necessary for our American factory heads to realize that, for example, sulphur black and direct black are as different as soap and wood pulp.

MR. SCHOELLKOPF: *Dyestuff manufacture does not lend itself to mass production. A very important problem is the manufacture of the intermediates.*

The most serious difficulty in introducing the dyestuff industry in this country is the fact that it does not lend itself to mass production. There are too many different kinds and shades of dyes necessitating frequent changes in apparatus and methods during the course of the year. This is a distinct disadvantage from an American point of view. The United States has always been most successful in mass manufacture of products of universal use. For instance, the manufacture of automobiles in this country is by far greater than anywhere else. American high cost of labor and natural inclination toward mechanical work favor such products as the automobile.

A very important phase of the dyestuff problem is the manufacture of the intermediates, such as Michler's ketone. We need a large ready stock of these. Some years ago Schoellkopf was influential in getting our government to place these on the free list, since they could be made much cheaper in Germany than in this country. We are now making intermediates in this country, but by no means enough. Mr. Schoellkopf thought that the suggestion made by Mr. I. F. Stone in his address at the Exposition of Chemical Industries (page 663 of our issue of Oct. 1, 1915) in regard to the Government manufacture of intermediates was timely.

In order to show that the manufacture of dyes was not an easy matter and required considerable experience, a list of some of the necessary apparatus was given. This included nearly every variety of apparatus known to the chemical industry. Since the dyestuff industry is subject to change of style a constant shifting of manufacture and, therefore, a great flexibility of apparatus is necessary.

Quite a few German colors are patented in this country for which there can be no competition. But fortunately most of the colors that now control the market are made according to patents which have expired. Mr. Schoellkopf said his own factory had been able to lower the prices from year to year by applying improved methods to old products. This they had done rather than try to make a great variety of new colors. They are making but 136 different dyes out of a possible 1000 now demanded by the textile and other manufacturers. Viewed from a manufacturer's standpoint he said the situation was also difficult owing to the shortage of supplies, including sulphuric and other acids.

Mr. Schoellkopf cited a number of stories from the daily press which greatly amused the audience. One newspaper account contained the recommendation of devoting a "room in each textile mill" for the manufacture of the hundred or more dyes required for that mill.

In concluding Mr. Schoellkopf summarized the immediate requirements of the American color industry as follows: (1) Cheap heavy chemicals; (2) cheap benzol, toluol, etc., (3) large supply of intermediates; (4) co-operation of the United States Government.

A paper on "The Dyestuff Situation in the United States" was then presented by Dr. **Thomas H. Norton** of the Bureau of Foreign and Domestic Commerce, who reviewed the situation and discussed the part of the Government in alleviating the situation. The country is now manufacturing enough aniline oil to satisfy the normal demand. The future depends on what the legislature will do next December. In 1913 about 3000 short tons of colors were made here. The imports were 25,000 tons, of which 22,000 tons came from Germany. In 1916 over 9000 tons will be made and by 1917 our production ought to be 16,000 tons.

DR. NORTON: *A plea for unity in the dye industry, a Government factory for intermediates, a Bureau of Standards for Dyestuffs.*

The largest hosiery mill in the United States and in the world employs 2500 operators. Ordinarily it requires 500 pounds of dyestuffs daily to cover the needs of its dyehouse. Four weeks ago its stock of colors had dwindled to half a barrel. About 160,000 dozen pairs of hose were stacked up awaiting dyes, and more than 1000 operatives were laid off.

Dr. Norton said that despite the efforts of the Government to secure the free passage of European dyestuffs to this country it has not succeeded in releasing more than 50 tons of dyestuffs of German origin since the middle of March, 1915. The powerful association of hosiery manufacturers has agreed to bear the burden of increased tariff duties on dyes of foreign origin, if that is necessary to secure the establishment of an independent American industry.

Dr. Norton made a strong plea for *unity* in the American dye industry. Financial, technical and commercial unity is absolutely necessary for success. He made the following recommendations:

(1) A Government factory for the production of the intermediates as proposed by Mr. Stone.

(2) A Bureau of Standards of Dyestuffs which would set a standard in the purity of dyes, would recommend best methods of dyeing wool, silk, etc., with the various dyes, would protect and help along the young industry and would serve in general as a bureau of information.

(3) A corporation made up of members of the various dyestuff *consumers*—all dyestuffs to be purchased through a central agency, which agency would be assisted by the national bureau. All consumers who would purchase imported dyes at "dumping" prices would be penalized or ruled out altogether.

Mr. **W. H. Childs** of the Barrett Mfg. Co. then presented a paper outlining the policy of the American Coal Products Co. and its subsidiary, the Barrett Manufacturing Co. He said that the manufacture of aniline oil was started by the Barrett Mfg. Co. in 1899, but was not a success, mainly on account of the competition from the foreign "Kartels."

MR. CHILDS: *History of Benzol Products Company. We need a protective tariff and a Scientific Tariff Commission.*

Later the Semet-Solvay Company and the General Chemical Company, together with the Barrett Company formed the Benzol Products Company. By 1913 this company produced 20 per cent of the aniline oil consumed in this country. The foreign concerns tried every means in their power to drive them out, but they continued manufacturing even though they lost money every year. Then came the war. On Jan. 1, 1915, they started manufacturing at their new plant at Marcus Hook, N. J., and are now producing a quantity in excess of the total consumption prior to the war.

Mr. Childs discussed at length the matter of protective legislation. We must realize that the peace perils of Germany and Japan are far more serious than their war perils. Tariff revision is a necessity.

Mr. Childs advocated the formation of a *scientific tariff commission,* this commission to be altogether non-partisan and to be composed of men and women such as Perkins, Edison, Logan, Byllesby, Mitchell, Jane Addams, etc. This commission would study the economic problems of the present and make well-founded recommendations to the Government.

A paper on "Common Sense on the Dyestuff Question" was read by Dr. **J. Merritt Matthews,** consulting engineer of New York City. He said that a great many textile manufacturers have the idea that dyes can be made in a small room by quick and simple means; they have not the faintest conception of the complexity of the aniline dyestuff manufacture. He deplored the propaganda which has been carried on by the newspapers, without doubt in good faith on their part, for numerous wildcat schemes for making dyes; they did not realize the harm they were doing by causing the public to believe the problem was solved and no further difficulties would be encountered.

DR. MATTHEWS: *Tariff protection for the intermediates is most important. Our country never prepared in the military sense without an "intermediate" industry.*

One of the most amusing of Dr. Matthews' stories was that of the owner of a large cranberry bog who wanted to make "cranberry red" from his cranberries, extracting the red dye without in any way impairing the food value. Dr. Matthews pointed out that the crux of the situation lies in the economic production of the *intermediates,* as well as ready supply of sulphuric acid and other necessary chemicals. What this country requires more than anything else to relieve the dyestuff situation is the firm and permanent establishment of the manufacture of the intermediates. We need tariff protection not merely for the dyestuffs, but chiefly for the intermediates, such as Michler's ketone.

It is to the Government's best interests to protect and foster factories for the production of the intermediates, not only for the sake of the dye and textile industries but also on account of the *military* importance of these factories in time of war.

Mr. **John P. Wood,** president of the National Association of Woolen Manufacturers, gave a short talk on the consumer's interest in dyestuffs, in which he stated that there was already sufficient power vested in the Government authorities to prevent dumping, provided it was rightly exercised, and he thought it was going to be a difficult matter to adjust conditions from the standpoint of tariff. The chemists must realize that the tariff is a political question, and they must not ignore present political conditions. The situation is, of course, grave, and the consumers are anxious to do all in their power to foster an American industry so that a repetition of the present conditions cannot occur. He explained the difficulty of obtaining Government action, and the long time needed for proper study of the tariff question. In a certain case a study of only one schedule occupied a period of two years, and then the commission which had made the study reported to the Government that its results were only partial and that it had not adequately finished the work.

MR. WOOD: *We need a tariff not only on dyes in bulk but on dyes that enter the country on cloth, leather, etc.*

He said the dyestuff industry was created out of a protective policy and the same policy ought to be followed now. But we must not only have a duty on the dyes in bulk, but also on the dyes that enter the country on cloth, leather, etc. Proposals made must take into account the fact that consumers need dyes now, immediately, and whereas ten years may ensue before a complete industry is established here, in the meantime the consumer needs the dyes and should be able to get them from somewhere.

Mr. **John Alden** of the Pacific Mills, Lawrence, Mass., commented further on the consumer's interest in dyestuffs. He said that our present supply of dyestuffs consisted of the following: (1) Old stock; (2) small amounts from Switzerland and England; (3) indigo shipped here from China; (4) colors from mills who have more than they need; (5) colors made in this country. To-day the mills are dependent on the last three items with the indigo from China being more or less uncertain. It costs 1 cent per yard more to produce fabric using the Chinese indigo. Many mills would be shut down if it were not for the colors made in this country from our own intermediates. Prices of dyes are very high and it costs more to produce the colors on cloth. For example, with the American navy blue the cost per yard of a number of goods has increased by more than 5 cents as compared with the German dye used before the outbreak of the war. In the same way the cost has increased for aniline black by 1 cent per yard, for wine by ¾ cent per yard, and for para red ⅞ cent per yard.

MR. ALDEN: *The shortage of dyes has quite materially increased the cost of dyed fabrics. This is serious.*

He said that the public had been led to believe through news from various sources that the dyestuff problem was practically solved and consequently the textile manufacturers had been prevented from raising the prices on their cloth very much.

Dr. **Wm. H. Nichols,** chairman of the board of the General Chemical Company, emphasized the great difficulties in carrying on the work of making dyes, and urged that great care be taken in starting new enterprises. He said that colors and intermediates cannot be created merely from the wish to do so, and that a great injury had been done by giving people the view that it is easy to make them. He attributed the success of the industry in Germany not

DR. NICHOLS: *Opening of general discussion. It is very difficult to make dyes efficiently on a large scale.*

merely to government protection, but to the intense application and devotion of the German to the science of chemistry.

Dr. **Chas. L. Reese**, chemical director of the du Pont Powder Company, said that his company is not manufacturing dyes and is not in a position to do so. It is making some intermediates for its own use, but does not intend to go into dyestuff manufacture.

Dr. **Wm. Beckers** of the W. Beckers Aniline & Chemical Works of Brooklyn, N. Y., considered protective tariff legislation as the most vital point in the whole dyestuff situation. The alizarine and indigo derivatives are still on the free list because formerly these dyes were agricultural products which could not be "raised" in this country on account of unsuitable climatic conditions. In consequence of these alizarine and indigo dyes being on the free list, our textile mills have favored these and slighted the aniline dyes. If this is continued the former products are apt to take the place of aniline colors, sulphur colors, etc. The carbazol products are the latest of this class, and the steady growth of these colors could result in their being developed to such an extent as to hurt the aniline dye industry. "The American dyestuff industry is a baby giant still asleep in his cradle, and it is our duty to see that his body and all of his limbs are properly developed and not one of his legs cut off."

DR. BECKERS:

Alizarine and indigo derivatives are still on the free list. This is a discouragement for the manufacture of aniline dyes.

Mr. **Herman A. Metz**, formerly Comptroller of New York City and president of H. A. Metz & Co., said that he represented all sides of the industry, being manufacturer, importer and consumer, and had also had a great deal to do with the tariff question. He said he had always advocated duty on all dyes or none, but that consumers here had backed up the free importation of alizarine dyes, as it of course meant a cheaper product to them and there did not seem to be any likelihood of their being made here. He said the situation demands immediate action as the consumers need the foreign dyes and are going to need them all during the time that the American industry is being developed.

MR. METZ:

The textile industry is much more important than the dyestuff industry. Textile men have a right to buy as cheaply as possible.

The American textile industry Mr. H. A. Metz considered much more important than the American dye industry and we must not impair or destroy the one for the sake of the other. "The dumping clause is all nonsense. The textile man has a right to buy at the lowest price obtainable. Everything else is theory and bunk."

Dr. **Marston T. Bogert** of Columbia University pointed out that the dyestuff industry is primarily dependent upon properly trained chemists. "The industry of producing the chemist is the fundamental industry of all." We ought to establish in this country an institute such as the Kaiser Wilhelm Institute in Berlin. The American university cannot very well meet the situation of supplying the proper material as regards efficiently trained chemists unless the country assists the university in its endeavors.

DR. BOGERT:

The industry of producing the chemist is the fundamental one. We need a Kaiser Wilhelm Institute in this country.

Professor Bogert was the last speaker. After a unanimous vote of thanks to the several speakers on the program the meeting adjourned at a quarter to twelve—one of the longest and most interesting meetings ever held at the Chemists' Club.

Coming Society Meetings

The New York Section of the **American Electrochemical Society** will hold its second regular meeting of the season jointly with the Illuminating Engineering Society on Thursday, Nov. 11, at 8 p. m., at the United Engineering Societies Building, 33 West Thirty-ninth Street, New York. The subject of the evening will be "Electrical Phenomena in Vapors and Gases," and the following interesting program is announced:

"Unstable States in Arc and Glow," by Mr. Walter G. Cady, Wesleyan University, A. E. S.

"Gaseous Conductor Light," by Mr. D. McFarlan Moore, Edison Lamp Works, I. E. S.

"Electric Arc in Complex Vapors at Reduced Pressures," by W. A. Darrah, Mansfield, Ohio, A. E. S.

The speeches will be illustrated by experiments and lantern slides.

Other meetings and lectures during November are:

American Chemical Society (New York Section) at Rumford Hall, Chemists Club, Friday, Nov. 12.

Society of Chemical Industry (New York Section) at Rumford Hall, Chemists Club, Friday, Nov. 19.

Franklin Institute Lectures, Philadelphia, Pa.:

C. H. Herty, University of North Carolina, "Turpentine Industry Development in the Southern States," Thursday, Nov. 4.

J. C. McLennan, University of Toronto, "Spectra, Their Origin and Some of Their Characteristics," Thursday, Nov. 11.

A. A. Michelson, University of Chicago, "On the Ruling of Diffraction Gratings," Wednesday, Nov. 17.

The School of Chemistry of the University of Pittsburgh

The new professional School of Chemistry of the University of Pittsburgh began its work on Sept. 27, 1915, under the deanship of Dr. Raymond Foss Bacon, director of the Mellon Institute of Industrial Research. A prescribed four-year undergraduate curriculum leads to the degree of Bachelor of Chemistry, and the staff of instruction includes the regular faculty of the university and fellows from the Mellon Institute of Industrial Research who are especially qualified in various theoretical and technical branches. This combination gives the new school the opportunity to offer not only the usual undergraduate and graduate courses in chemistry and technology, but also specialized work under men who are experts in specific American industries. In addition, thirty special lectures by prominent chemists and technologists in the Pittsburgh district, have been arranged for the academic year 1915-16. Attendance at these lectures is required of the student body, but they are also open to the public.

The professorate of the new school is constituted as follows: Alexander Silverman, M.S., professor of chemistry and head of the department of inorganic, analytical and physical chemistry; David S. Pratt, Ph.D., professor of chemistry and head of the department of organic, sanitary, and micro-chemistry; Samuel R. Scholes, Ph.D., E. Ward Tillotson, Jr., Ph.D., and Edmund O. Rhodes, M.S., professors of applied chemistry; Benjamin T. Brooks, Ph.D., professor of chemical engineering; William A. Hamor, M.A., professor of chemistry; Henry A. Kohman, Ph.D., and Harold Hibbert, Sc.D., professors of applied organic chemistry; Leonard M. Liddle, Ph.D., and R. Phillips Rose, M.S., professors of organic chemistry; Lester A. Pratt, Ph.D., professor of inorganic chemistry; and C. C. Vogt, Ph.D., professor of physical chemistry. Thirteen assistant professors and ten instructors complete the teaching staff of the school.

Zinc Oxide from Lead Blast Furnace Slag, as in Operation at South Chicago

BY H. B. PULSIFER

When the "National" plant of the American Smelting & Refining Co., located at South Chicago, Ill., was dismantled[1] early in 1915 some of the buildings were spared

FIG. 1—GENERAL VIEW OF PLANT—DUMPS, CRANE, FURNACE BUILDING AND STACK

FIG. 2—CRANE ON DUMP (LOOKING TOWARD LAKE)

and the place was leased to Messrs. Hedges and Divine for the recovery of zinc oxide from the slag dumps.

B. F. Hedges had been superintendent of the refinery[2] for over seven years and R. D. Divine had been metallurgist at the same place for some years. These men had previously made several laboratory tests and short experiments, even, with the large blast furnace to study the expulsion of the zinc from slag on heating with limestone and coke. They had the courage and confidence to make alterations, install the additional equipment necessary and start operations at their own expense. Cheerful to relate, the experiment is successful; their hopes are largely fulfilled, and each day's operation adds to their profits.

The process consists of smelting the refinery slags in the lead blast furnace with additional lime and considerable coke on the charge; the furnace is run with hot top and the heavy zinc fume is collected in bags as the finished product of the operation.

The principle of the process is not essentially different from similar work as carried out at the Oker plant in the Harz[3] mountains or in California plants[4], which have smelted copper ores high in zinc with volatilization of more or less of the zinc. The condition of best operation as at present worked out is worth attention, while the successful prosecution of the experiment will doubtless be copied with renewed vigor wherever circumstances shall allow.

THE SLAG DUMP

The slag dump as left by the lead refining operations covering a quarter century covers a space of some 4 acres and contains a maximum of possibly 150,000 tons of slag running over 10 per cent metallic zinc. Fig. 1 shows the plant and the dumps as seen from the side next Lake Michigan; Fig. 2 is another view of the ground, this time looking east, toward the lake. Certain spots in the dump will probably contain as high as 15 per cent zinc; it will mostly average 12 per cent, but some piles of coal ashes will have to be moved to get at the slag under them. The slag is, of course, practically all that runs from the lead blast furnaces previously charged with the refinery residues. The zinc came from the skimmings off the refining furnaces after the

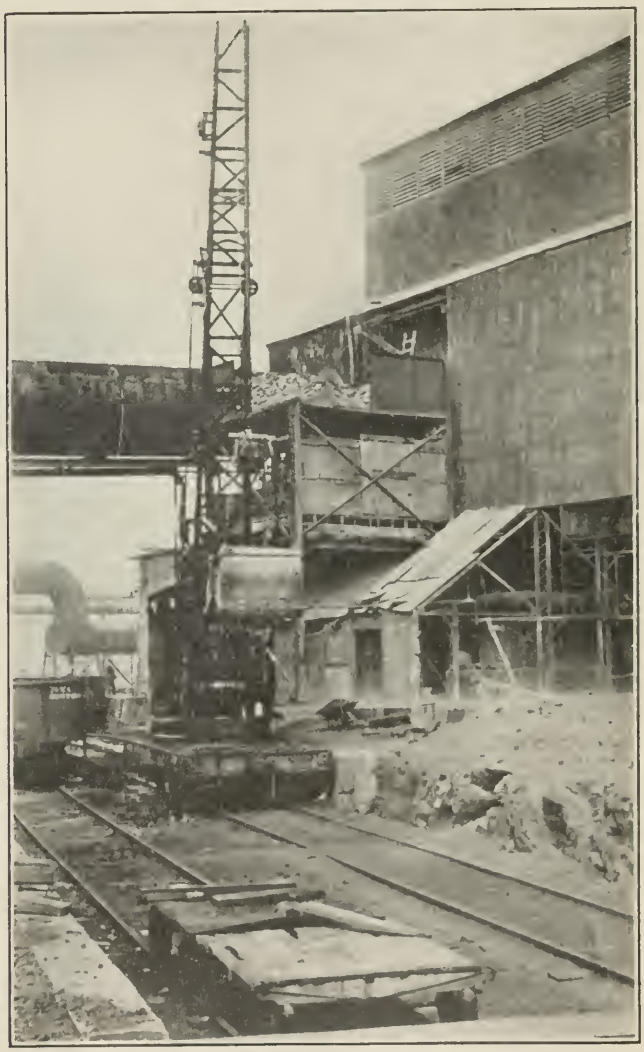


FIG. 3—CRANE AND SLAG HOPPER OVER FEED FLOOR OF BLAST FURNACE

[1]Mining & Eng. World, Jan. 2, 1915; p. 16.
[2]Mining & Eng. World, July 26 and Aug. 2, 1913.
[3]Eng. & Min. Journal, April 10, 1910; p. 819; and Eng. & Min. Journal, June 3, 1911; p. 1109.
[4]Mining & Eng. World, Feb. 10, 1912; p. 338. Eng. & Min. Journal, Feb. 29, 1908; p. 443.

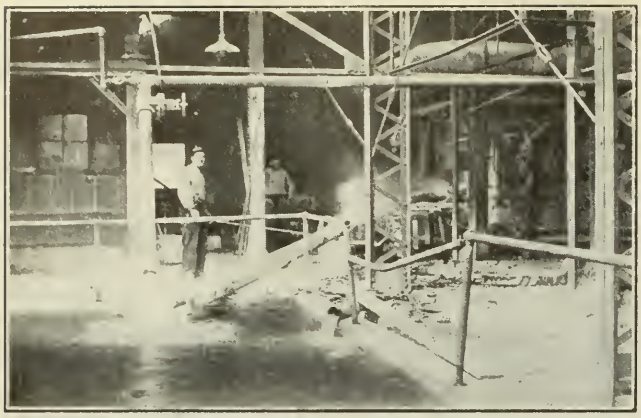


FIG. 4—SLAG FROM BLAST FURNACE RUNNING INTO GRANULATING TANK

desilverization by the Parkes process, this skim, along with many other residues and materials, constituting an important part of the blast furnace charges.

HANDLING THE MATERIALS

This is accomplished by the Browning locomotive crane, as seen in Figs. 1, 2 and 3. The crane digs out the slag and carries it to the hopper above and close to the feed floor of the furnace. The granulated slag is lifted out of the granulating tank by the same crane and deposited in cars or taken back to the dump on the water front, as desired. The limestone, coke, and any other materials can be brought to the furnace by the tracks, bins and elevator formerly used for the same purpose. The locomotive crane was new equipment supplied by Hedges & Divine.

THE BLAST FURNACE

The former bullion blast furnace, which had long been used in a shortened condition, was lengthened out from five to nine jackets on a side, making the furnace now

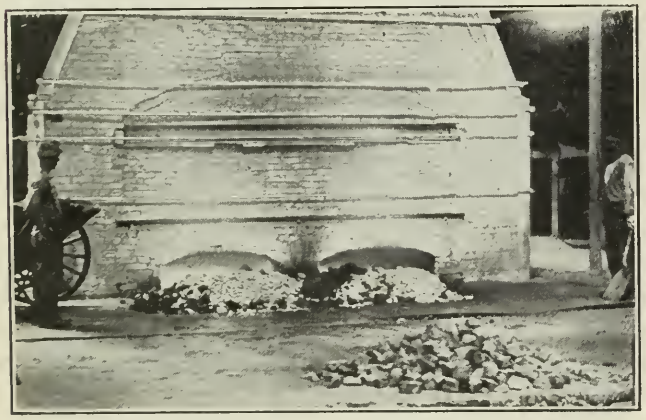


FIG. 5—FEED FLOOR OF BLAST FURNACE

about 46 in. x 156 in. at the tuyeres. The crucible and curb were built up another foot to get more fall to the granulating tank, while the inside capacity of the crucible was largely filled in, and has since become entirely so, slag and lead now flowing out together into the small pot forehearth. Raising the jackets shortened the curtain of brickwork above them up into the shaft but presented no difficulty. From the settling pot the slag flows out through a trough into the granulating tank well shown in Fig. 4.

Considerable experimentation as how best to feed the furnace finally resulted in low hand feeding from one side only. A charge ready to be pushed in is seen in

FIG. 6—FAN AND FLUES IN FAN ROOM

Fig. 5. A charge buggy is seen at the left of the print; only a few feet further to the left are the feed-spouts, which draw into the buggies from the overhead hopper as seen in Fig. 3. The top of the charge is kept nearly at the level of the feed floor; the top is usually red hot; a dense white fume subdues the flickers of the red (calcium) and green (zinc) flames which play up into the big brick flue head.

The furnace is now running smoothly on 12-oz. blast and taking around 65 tons per twenty-four hours. The charge consists of the dump slag, limestone and coke (partly coke breeze). Recovery of zinc is probably not

FIG. 7—BAG ROOM—DISCHARGE ENDS OF PRINZ & RAU MACHINES

over 50 per cent, for the granulated slag still goes some 5 per cent zinc. Besides the oxide driven off there is a noteworthy recovery in lead bullion and speiss—a ton or so each day. This bullion and speiss is, of course, silver-bearing. No change was made in the tuyeres for the new work; there are nine on each side, one to each of the cast-iron jackets; they are approximately 3.5 in. inside diameter. No crusts or hangs have yet appeared inside jackets or shaft after more than two months' steady running.

COLLECTING THE OXIDE

The white oxide which is evolved from the charge in billowy puffs is drawn through about 700 ft. of steel flue by a fan at the bag house. This fan is a No. 80 exhauster made by the Clarage Foundry & Machine Co. of Kalamazoo, Mich. An Allis-Chalmers direct-current

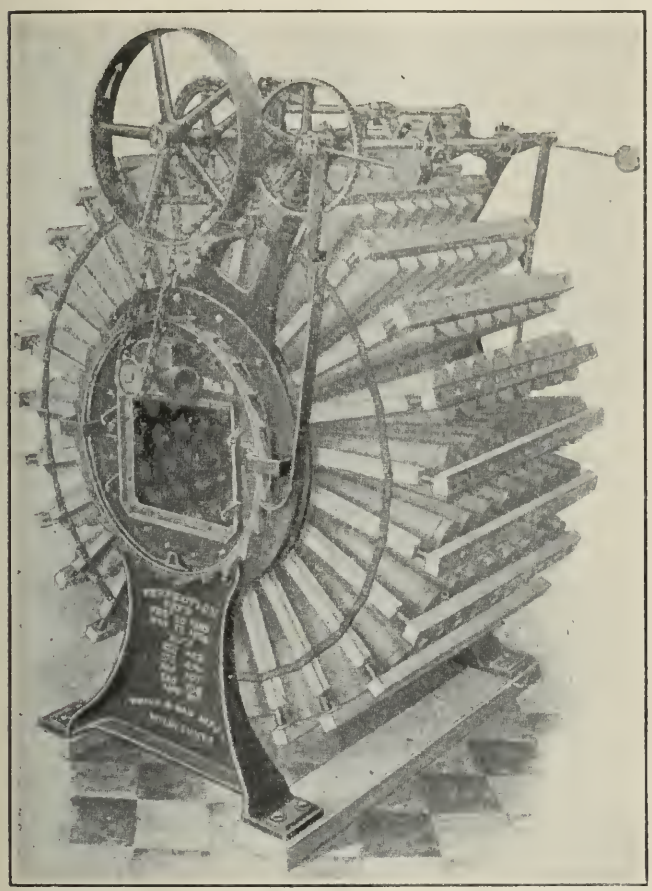


FIG. 8—THE PRINZ & RAU DUST COLLECTOR

motor, 25 hp., taking 220 volts and 96 amp. at full load, pulls the fan.

Fig. 6 shows the intake flue on the left; cooling air enters at the square orifice between that and the pipe to the bags, which comes out at the right. The temperature of the gas is held just under 200 deg. Fahr. A rather heavy fume settles out and builds up in the flue nearer the furnace; this is removed mostly through hoppers, but to get it all out the furnace must be temporarily banked so that men can enter.

Fig. 7 shows the last stage of the recovery. Here the oxide is collected in six Prinz & Rau dust collectors and the bags are filled. This bag room immediately adjoins the fan room. The flue from the fan is divided to supply each of the six machines; from the machines the collecting flue for the gases leads through another fan to the stack so conspicuous in Fig. 1. Unless a bag is damaged and leaks there is no visible exhaust from the bags. The Prinz & Rau machines have many small bags in lines under one supporting base for each line. As each line of bags comes vertical on the cycle the motion halts, the pressure has already died out in that line of bags and a sharp knocking dislodges the collected oxide; then the machine starts another notch to bring perpendicular the next line of bags, the cleaned bag is again inflated and passes downward around the axis. The dislodged oxide falls into a trough; a screw conveyor works it forward to the inclined trough, falling sharply into the paper bag. A full bag has averaged 55 lb. weight, the product containing about 74 per cent zinc and 6 per cent lead.

With the present fancy prices for spelter and oxide the recovery of some 3 tons of oxide a day represents a very respectable profit on the venture. Recovery is, however, far from what might be wished, while the cost of fuel is somewhat large. Further work ought certainly to remedy these defects. There is here a splendid example for further efforts on other dumps and at other plants. Not so very much of improvement would make the process workable on many a zincy dump; not much imagination pictures slag running from blast furnaces into converters (such as the Fink furnace) for the recovery of zinc after smelting for lead without intermediate cooling of the slag.

Removing Iron Scale by Pickling; Theory vs. Practice

BY CARL HERING

When iron is worked into sheets, wires, tubes, etc., the well-known bluish-black scale is produced each time that it is heated to the annealing temperature, or in the case of tubes, to the welding temperature. This hard scale must be removed before the metal can be again rolled or drawn, or before it can be tinned or galvanized. This is usually done by immersing the oxidized metal in sulphuric acid, which is termed "pickling."

Many persons are contented with the knowledge of this fact that iron thus coated with scale can be cleaned by immersing it long enough in sulphuric acid; the method has been known and used for generations. Those manufacturers whose motto is to "let well enough alone," that is, those for whom the methods of their fathers and grandfathers are good enough, are satisfied with this process.

The progressive manufacturer, however, who believes in looking after leaks, will do well to study this process more carefully. This black oxide of iron is Fe_3O_4 and it will be found that this is not soluble in sulphuric acid, at least only with difficulty at objectionably high temperatures. In a test recently made by the writer, a piece of the scale alone, without any metallic iron, was immersed for a prolonged time in rather strong sulphuric acid (sp. gr. 1.2); no gases were evolved and it was found to have lost no weight. It may be that some varieties of Fe_3O_4 are soluble, but this hard, bluish-black kind produced in the annealing furnaces, does not seem to be. At rather high temperatures solution is claimed to take place, but such temperatures cause acid fumes to be generated which are very objectionable.

A possible reason for its not being soluble is the equation $Fe_3O_4 + 3H_2SO_4 = 3FeSO_4 + 3H_2O + O$ which shows that free oxygen would have to be evolved if it were soluble. As this oxygen was combined with the iron it presumably requires a supply of energy to free it. Moreover as this oxygen must be changed from its solid form in the oxide, to the gaseous form, still more energy is required to supply the latent "heat," or more correctly, the energy of volatilization.

As the oxide is already in a low state, from the energy standpoint, little if any energy can be expected to be set

free by its solution. Hence it seems to be necessary to supply some energy from external sources. In the usual pickling process this is supplied by the dissolving of some of the metal itself, whereby good metal and acid must be consumed.

The action in the usual pickling process is therefore not a direct solution of the oxide. The scale is removed partly by dissolving the iron underneath it, and partly by forcing it off by generating hydrogen gas between the scale and the surface of the clean metal by the dissolving of the metal by the acid. It is possible that some of the hydrogen evolved by the dissolving of the iron, combines with the oxygen which must be set free, and that an actual solution of the scale then takes place in part at least; if so, less external energy would have to be supplied.

But in any case, the action in the usual pickling process is dependent fundamentally on the dissolving of some of the good metal, and not on the dissolving of the scale alone. The dissolving of good metal is not an incident in the process, but is a necessary part of it.

The process is therefore intrinsically incorrect in principle, as it is not a true dissolving of the scale, but must consume good iron and a corresponding amount of acid. The scale is not dissolved (or only partly) but the good metal is.

In the electrolytic process, however, the action is reversed; the scale is rendered readily soluble and the metal insoluble, hence it is correct in principle, the scale alone being dissolved. In this process, first brought out by C. J. Reed, and patented by him, the iron is made the cathode, not the anode as was suggested before. In an experiment recently made by the writer, a sheet of this scale alone without any metal attached, was made the cathode in sulphuric acid, and it was found to go into solution very readily when a current was passed, thus showing that when made the cathode, this oxide dissolves readily. It is not reduced to metallic iron, but goes into solution as oxide.

The reason, apparently, is that the tendency to develop hydrogen at the cathode reduces this higher oxide to a lower one, which then is soluble chemically; or perhaps the higher oxide or the partially reduced oxide is dissolved electrochemically, as we know it is in the case of the peroxide of lead on the cathode in a nitrate of lead bath.

Another factor is that the energy which it seems must be supplied when this oxide is to be dissolved in sulphuric acid is now supplied by the current, and it is certainly much cheaper to generate this energy in a dynamo than by dissolving good metallic iron in sulphuric acid, as in the ordinary pickling process of our forefathers.

But whatever be the explanation, the facts are that this oxide is readily dissolved in sulphuric acid when made the cathode. It is also a fact that when the current density is high enough to keep the clean metal covered with hydrogen, no good metal will be dissolved. Hence it is correct in principle; it will dissolve the scale only, will not dissolve any good metal, and will require the consumption of only as much acid as is necessary to dissolve the scale.

Although the amount of good metal and acid consumed in the ordinary pickling process, and saved by the electrolytic process, may be small relatively to the weight of the article pickled, yet when many tons of steel are cleaned per day, as in some large works, the value of these unnecessary wastes amounts to considerable. Mr. Reed (see Trans. American Electrochemical Society, Vol. XI, p. 182) estimates that this saving would be about 50 to 75 cents per ton, amounting in a single works to from $2,000 to $3,000 per day.

Another advantage lies in the fact that the oxide is sometimes formed in rather deep pits. To remove this by the ordinary pickling process would require a prolonged immersion, which would dissolve much good metal and probably make new pits, besides appreciably changing the thickness of the wires, sheets and tubes. The cost increases greatly when the oxide is in deep pits or adheres so tightly that it is difficult to dissolve the metal beneath it. While in the electrolytic process the oxide in such pits merely requires a longer treatment, but does not dissolve any metal, nor does it consume any acid uselessly.

In the case of tubes, the removal of the scale by the ordinary pickling process, sometimes involves the consumption of so much of the good metal that the tubes become seriously roughened and reduced in size and strength.

The anode in this process is most conveniently made of lead. The ordinary scale is removed in about a minute's treatment, less when thinner and more when thicker. The cost of the electric energy is very small, amounting to only a few cents per ton of wires and sheets. The iron comes out of the bath almost white, resembling silver, in marked contrast to the dirty gray appearance in the ordinary pickling process. It is then probably also in much better form for galvanizing and tinning.

In a recent test made by the writer under the ordinary conditions of pickling, that is, with dilute acid and at high temperatures (near the boiling point), the consumption of steel from sheets from which the oxide had been removed, was found to be about 1¾ lb. per thousand square feet per minute of immersion. It is, therefore, quite great, amounting to many tons per day in large works. Roughly, the acid required to dissolve this metal has about the same money value as the steel, or a little more, assuming the latter to be of good quality and to have had considerable work done on it. Both are unnecessarily wasted, as the above does not involve the acid usefully used to dissolve the scale.

Moreover, the surface of the steel which had been thus treated for about 50 per cent longer time than required for the pickling, was found under the magnifying glass to be full of fine pin holes and to be porous, hence would require far more tin or zinc to coat it, if, indeed, it could be well coated at all. A corresponding test made under electrolytic pickling conditions, while current was flowing, showed that no steel was dissolved.

In another test made by the writer, one electrode was made of a slab of scale alone (without iron), the other of cleaned iron, the solution being the hot, dilute one used for ordinary pickling. This was found to act as a battery of about 0.12 volt, the current in the liquid flowing from the iron to the scale, hence dissolving the iron. This shows that in the ordinary pickling operation, a local electrochemical action exists which dissolves the iron at the exposed parts.

A statement often made, especially by those who have little respect for scientific investigations, is that in specific cases practice has shown theory to be wrong. The present case is one in which it may be said that theory has shown the practice of many years to have been wrong.

The present war, so disastrous to Europe, has given a marked impetus to exports from this country, and if by reducing the cost of manufacture by such saving of waste and by other economies, the selling prices can be reduced, this country might be able to enjoy the markets of the world after the war. It is the well-known lack of attention to the saving of waste and to the smaller economies, which is an important factor in depriving us of the markets of the world in competition with other nations which give more attention to such details.

A Rapid Precise Standardization of Acid Solutions

By MERLE RANDALL AND CHARLES C. SCALIONE

A choice of a reliable method for the standardization of acid solutions has been the subject of extensive researches. We shall not attempt to devise a new method. We wish, however, to bring to the attention of analytical chemists, and to adapt to the technical laboratory, the sodium carbonate method used by Richards and Hoover,[1] in the determination of the atomic weights of carbon and sulphur.

This method has the advantage of extreme simplicity, accuracy and rapidity.

Aside from the personal factor of the analyst, the accuracy of a standardization depends on the accuracy with which the acid is measured and upon the definiteness of composition and amenability to weighing of the standardizing substance. Barium sulphate is of indefinite composition, very difficult to filter and weigh, and can be used only for standardizing sulphuric acid. Silver chloride has a definite composition, but its application is limited to hydrochloric acid. The method is tedious, and without extreme precaution and large expenditure of time, its use is less accurate than the sodium carbonate method described below. Because of varying atmospheric conditions substances containing water of crystallization are of indefinite composition. Powdered substances, like Iceland spar, are not definite in composition due to the varying content of absorbed water. Sodium carbonate of sufficient purity, except in respect to water, is available in most laboratories. If not available it can be easily purified by recrystallization in glass or porcelain, or in an ordinary platinum dish if extreme precision is desired. Richards has repeatedly shown that the only reliable method of completely removing absorbed water and other gases is to fuse the substance. Sodium carbonate can be easily fused.

Procedure.—Weigh out roughly into a previously ignited and tared platinum crucible half a gram of pure sodium carbonate. Provide the crucible with a rose crucible cover and pipe stem delivery tube. (A hard glass delivery tube is satisfactory.) Heat slowly to fusion, on a pipe stem triangle, in a slow stream of carbon dioxide from a commercial carbon dioxide cylinder,[2] connected to the pipe stem delivery tube of the crucible by means of a rubber tube. Keep fused three minutes. Remove the flame and allow the salt to cool in the stream of carbon dioxide. While the salt is in a fused condition and cooling, the stream of carbon dioxide is increased. This serves to prevent the decomposition of any of the carbonate as well as to cool the crucible quickly. Run out from a tared weight burette[3] into a beaker flask a quantity of acid roughly estimated to be a little less than that required to neutralize the sodium carbonate employed. Carefully weigh the cool crucible containing the fused salt, then introduce it into the acid solution, covering the beaker with a watch glass. When violent action has ceased boil the solution a few minutes. Allow to cool and when fairly cold introduce a few drops of methyl red indicator[4] Complete the titration drop by drop, with acid drawn from the weight burette previously used. The process may, of course, be conducted with even less trouble by adding at first a slight excess of acid and titrating back with a very dilute hydroxide.

Experimental.—The researches of Richards and Hoover have shown that the accuracy approaches that of the atomic weights. The accuracy in less experienced hands is high. The following new data are presented:

Sodium carbonate containing 5.97 per cent of water was re-fused five times in a current of carbon dioxide. The successive weighings were, 8.43539, 8.43543, 8.43540, 8.43538, 8.43542. No change within experimental error took place.

Dilute hydrochloric acid was standardized by the above method. The results are given in the following table:

No.	Weight of Acid Solution	Weight of Fused Na_2CO_3	Na_2CO_3 per Gm. of Solution	Per Cent HCl
1	261.01	0.5247	0.002010	0.1507
2	151.24	0.3043	0.002012	0.1509
3	113.69	0.2286	0.002011	0.1508

A student using this method for the first time with a strong sulfuric acid solution obtained 26.32 per cent, 26.34 per cent and 26.33 per cent H_2SO_4. A complete standardization can be made in forty-five minutes. The method is applicable to any strong acid and with choice of a suitable indicator to any weak non-volatile acid.

We believe that this method of fusing sodium carbonate in a current of carbon dioxide is more rapid than any other method of bringing a standardizing substance to constant weight. The other manipulations require no more time than those of other standard methods.

Chemical Laboratory, University of California,
Berkeley, Cal.

[1]Richards and Hoover, J. Am. Chem. Soc. 27, 95, 108 (1915).

[2]Carbon dioxide from commercial cylinders is the most convenient. If it is not available carbon dioxide produced in a Kipp generator with acid and marble and passed through cotton to take up the acid spray and then over calcium chloride, will be found satisfactory.

[3]For ordinary work a volumetric burette may be used; but for accurate standardization the weight burette is recommended. A weight burette can be made from a thin-walled glass-stoppered separatory funnel of suitable size by drawing off a tip close to the stopcock. A small test tube provided with a perforated cork is a satisfactory covering for this tip during weighing. The pipette can be suspended from the balance beam while weighing by means of a fine wire loop. Ordinarily the time for weighing the burette is less than that required for the proper drainage of the volumetric burette.

[4]Methyl red is recommended but if not available methyl orange will be satisfactory. Methyl red will be found very advantageous as there is only a two-color change from alkali to acid while methyl orange shows three. For a full discussion see Richards and Hoover. *loc. cit.*

Thermal Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

(*Continued from page* 720)

I had for several years past investigated the subject of the amount of the moisture in the atmosphere as measured by local determinations of the dew point, and as taken from the records of the Weather Bureau, with a view of determining the effect of a given weight of water-vapor on the economy of the furnaces, the ultimate object being to find the relation between the cost of removing the moisture and the value of the saving so made.

Curves of fuel consumption for the year, taken from the furnace books for the corresponding weeks in several years and averaged, were of exactly the same general shape as the curve of annual humidity, but, calculating the effect of the humidity on the basis given by Bell, failed to account for more than a small part of the effect produced.

No adequate explanation was forthcoming until an analysis of the top gases was made, which should have showed a very considerable quantity of hydrogen based on the moisture contents of the blast, but which actually showed very little. This proved very clearly that the hydrogen formed at the tuyeres by the dissociation of the moisture took oxygen from the ore at a higher level in the furnace, where the temperature was sufficiently low to permit the simultaneous existence of water-vapor and carbon, and that in this operation the hydrogen restored as much heat as the original water-vapor had absorbed for its dissociation, so that the explanation

of the loss caused by the presence of water, mentioned above, was not the true one at all.

It then became clear that the heat was absorbed at the tuyeres or in the bosh during the process of combustion (it being entirely impossible for water-vapor to exist in the presence of incandescent carbon) and, being a first charge on the assets of the combustion, was deducted from the already scanty supply of available heat, so that its effects were of the same order and degree, but of opposite kind from those produced by hot blast.

The calculations of available heat with moisture present have to be modified from those of dry blast, because part of the oxygen required for the combustion of the carbon is furnished by the moisture, and the air required per pound of fuel is accordingly diminished.

To illustrate, let us take the case of air containing 0.75 lb. of moisture per 1000 cu. ft., or (on the basis previously explained) per 75 lb. of air, corresponding to spring and fall conditions, with blast and critical temperatures as before, 1000 deg. Fahr. and 2750 deg. Fahr. respectively.

The oxygen in 75 lb. of air is 17.25 lb. and in 0.75 lb. of water is $\frac{8}{9} \times 0.75 = 0.667$ lb.; that is, $17.25 \div 17.917 = 96.28$ per cent of the total oxygen comes from the air.

The air per pound of coke is therefore $0.9628 \times 5.22 = 5.022$ lb. and the heat brought in by it is 1192.7 B.t.u.

The total heat of water-vapor per pound at 1000 deg. is 1552 B.t.u., and the water-vapor being just 1 per cent of the air by weight, the quantity brought in is 0.0502 lb., so the total heat brought in by it is 78 B.t.u. The heat of combustion and that brought in by the coke remain the same, so the total assets of the combustion become 6152.6 B.t.u.

The heat taken out by the nitrogen is 2594.6 B.t.u., that by the hydrogen is 52.4, and that by the dissociation of 0.0502 lb. of water is $\frac{0.0502}{9} \times 61{,}560 = 342.5$ B.t.u. The heat removed by the CO is, as before, 1431.6, or a total thermal expenditure of 4421.1 B.t.u., leaving as the heat available 1431.6 B.t.u. against 1697.5 B.t.u. with dry blast; all other conditions remaining the same. This is a reduction of 15.6 per cent, just about the difference in fuel consumption that is found in practice under the given conditions. If the same loss were referred to the 6000 B.t.u., which represent the approximate total heat development from 1 lb. of fuel, the loss would be 4.4 per cent, which is an insignificant fraction of the actual results in practice.

The results given in Fig. 1 were obtained by a series of calculations similar to the above.

It is hoped that these diagrams will have more than an academic interest to furnacemen, as they furnish an easy means of determining the probable results in fuel economy of any change in the temperature or humidity of the air. They also furnish the means of determining the increase in blast temperature necessary to counteract the effects of a given variation in moisture. While it does not now seem likely that we shall ever obtain stovemen who will determine the moisture from hour to hour, and proportion the blast temperature to meet it, the thing is not impossible; and if some genius would kindly invent a recording and direct-reading instrument for measuring the humidity of the atmosphere, this result might be achieved in fact.

These results, being based on what is supposed to be a new theory of the action of heat and moisture in the blast, will naturally be viewed with some skepticism, so that proofs of their substantial accuracy are in order.

Fortunately the data supplied by Mr. Gayley furnish an admirable opportunity. The critical temperature alone is lacking, but from the kind of iron made may be assumed to have been 2750 deg. Fahr. The humidity, before the dry blast was used, averaged about 5.25 grains per cubic foot, or 0.75 lb. per 1000 cu. ft., and the blast temperature was 720 deg. Fahr. After the application of the dry blast the humidity was about 2 grains, or, say, 0.3 lb. per cubic foot, and the blast temperature was 870 deg. Fahr. By interpolation on the diagram we find the available heat in the two cases to be 1090 and 1420 B.t.u. per pound of fuel respectively. The coke-consumption before the change was about 2140 lb. and, to be in inverse proportion to the available heats, should have been 1640 lb. after the change. Actually it was 1700 lb., a difference which is certainly no larger than might reasonably be expected, considering the many other factor varied. Notable among these is the increased ratio of CO_2 to CO in the top gases, with the correspondingly increased tendency of these gases to dissolve carbon from the fuel in the upper part of the furnace, and prevent its reaching the hearth.

This feature, of which, obviously, the diagrams can take no cognizance, is of the first importance in an exact determination of results.

At many works the effects of the higher humidity of the summer are masked by the fact that the furnaceman carries a higher heat in summer than in winter, either deliberately and for purpose of neutralizing the effect of the humidity, or simply because he finds that the furnace will stand more heat without sticking or other objectionable results. But at the furnaces with which the writer is connected, a constant temperature of 850 deg. is carried the year round, and under these conditions the variation in fuel is clearly apparent, the fuel per ton of iron being about 20 per cent more in the most humid weather than in the dryest. The critical temperature at these furnaces is known to be about 2750 deg. Fahr, the average low humidity is about 0.25 lb. water-vapor per 1000 cu. ft., and the average high humidity is about 0.95 lb. For these conditions we find from the diagram that the available heats are 1400 and 1160 B.t.u., which are in the ratio of 1.20 to 1, or precisely the same as the fuel consumption in the two cases.

In order to obtain a wider range of comparison, I have taken the work of a two weeks' period in two successive years (at precisely the same season in each) done by a small charcoal blast furnace, working with cold blast one year and hot the next.

The comparison is not very satisfactory, because the critical temperature could only be obtained approximately in one case and estimated in the other, the percentage of lime used being twice as great for hot blast as for cold, with a correspondingly great influence on the critical temperature (as will be explained presently). Moreover, in the cold-blast campaign a considerable quantity of cold slag was charged, to overcome the tendency to work "dry," which was not done in the hot-blast campaign.

The recorded fuel-consumption in the two cases was in the ratio of 1.7:1, while the available heats based on the probable critical temperatures in the two cases and without allowance for the remelting of the additional slag in the cold-blast campaign are as 1:2—a reasonable correspondence, considering the circumstances.

I recently found what appeared to be an authoritative statement, that at the Clyde Iron Works (England) the fuel consumption in January-August of 1829, 1830 and 1833, with cold, warm (300 deg.), and hot (600 deg.) blast respectively, was 8 t., 1 cwt., 1 qr.; 5 t., 3 cwt., 1 qr.; and 2 t., 5 cwt., 1 qr., or fuel consumption in the ratio of 3.42:1.56:1, while the available heats, with a

critical temperature of 2750 deg. and average moisture, are as 1 : 1.73 : 2.63, a correspondence which is not by any means accurate, but considering the magnitude of the saving and the probable effects of secondary results is not at all to be despised.

Other considerations of the same general kind in which the data are not available for quantitative comparisons will be given later, but will best be preceded by some remarks on the determination of the critical temperature.

Determination of Critical Temperature.—The paucity of published data of definite character on this subject led me to attempt direct experimental determinations.

This seemed a field in which a radiation pyrometer might be employed more conveniently than any other, and with the advantage of absolutely self-luminous bodies to observe. Accordingly, a Mesuré & Nouel "lunette" pyrometer was obtained. This instrument is not exact, and, for wide ranges of temperature, particularly at the upper or lower extremities of the scale, could not be trusted very far; but for a limited range near its center results obtained by any reasonably careful observer are closely comparable.

Many thousand observations were made with this instrument upon the iron and the cinder, where they flowed over their respective dams, at every stage of many hundred casts.

At first no connection whatever could be observed between the condition of the furnace, the kind of iron being made, and the reading of the pyrometer. Sometimes, it would show much higher temperatures with white iron than with gray, and, again, it would give the opposite result, until I almost gave up hope of getting any information as to the action of the furnace from it. But finally, I observed that the readings were influenced almost solely by the relative calcareousness or siliceousness of the slag, and the difficulty of interpretation then disappeared.

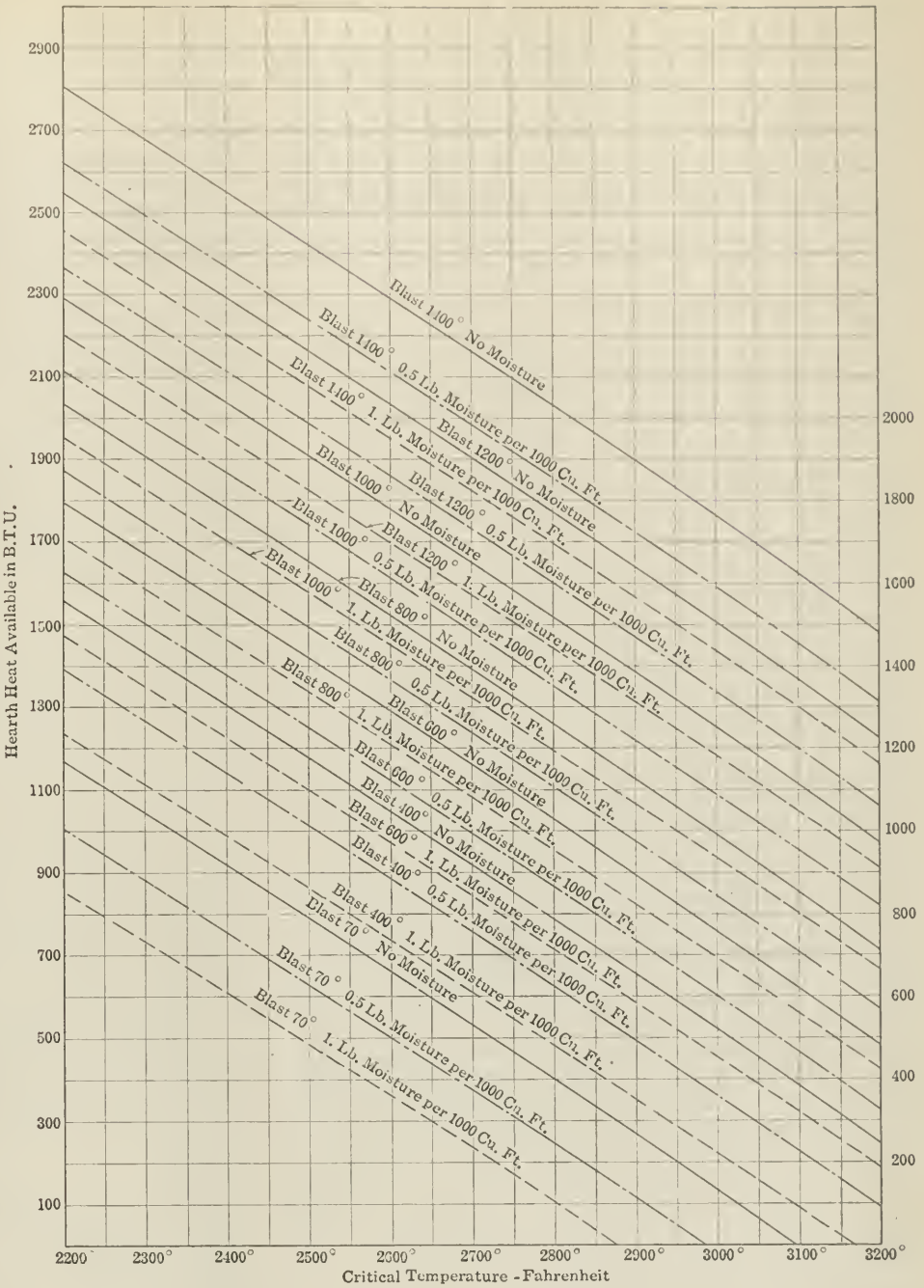

Hearth Heat Available in B.T.U.
Critical Temperature - Fahrenheit
Blast 1100° No Moisture
Blast 1100° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1100° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 1200° No Moisture
Blast 1200° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1200° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 1000° No Moisture
Blast 1000° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1000° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 800° No Moisture
Blast 800° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 800° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 600° No Moisture
Blast 600° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 600° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 400° No Moisture
Blast 400° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 400° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 70° No Moisture
Blast 70° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 70° 1. Lb. Moisture per 1000 Cu. Ft.
2900
2700
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
300
100
2000
1800
1600
1400
1200
1000
800
600
400
200
2200° 2300° 2400° 2500° 2600° 2700° 2800° 2900° 3000° 3100° 3200°

FIG. 1—HEARTH HEAT AVAILABLE PER POUND OF COKE, COUNTING 0.85 LB. OF FIXED CARBON ACTUALLY BURNED IN HEARTH, WITH DIFFERENT CRITICAL TEMPERATURES ALSO DIFFERENT BLAST TEMPERATURES AND DIFFERENT MOISTURE CONTENTS IN THE BLAST

One or two things were eventually brought out with great clearness which are not recorded elsewhere, so far as I know, and are therefore given here, since, though they may be known to others, their publication may still serve to bring out valuable discussion.

The first point noticed was the absolute collapse of the old notion that gray iron was always made in a hot furnace, and white iron in a cold one. (The furnaces were working on basic iron, and the silicon was therefore limited to 1 per cent, so that gray iron in this case means iron with only about this percentage of silicon.)

The next observation was that, in spite of the common statement that black cinder is made because the furnace gets too cold, the black cinder, in reality, was very frequently much hotter than the light.

On the other hand, the old founders' saying that "lime gives heat to the furnace" was confirmed completely, the cinder being without exception hotter in proportion, as it was more limy, as long as the furnace continued to make good iron. Even when the iron became hard, the cinder might still be at its very hottest if very limy.

It was also noticed that the cinder always controlled the temperature of the iron, and that as long as no cinder came through the tap-hole the temperature of the running iron remained practically constant, but as soon as the cinder came the temperature of the iron went up considerably and became the same as that of the cin-

der, which was always decidedly higher than the previous temperature of the running iron.

These observations, confirmed so many times that their accuracy for the given conditions could not be questioned, made it plain that, since the cinder became less fusible as it became more calcareous, it remained longer in the bosh, exposed to the heating action of the ascending gases, before acquiring the high fusion-temperture at which it could flow down into the hearth, while less calcareous slags melted sooner and ran down out of the range of action of the products of combustion.

The cinder, moreover, exercises a deterrent action on the iron as it drips down through the bosh, and by delaying its passage longer, as well as by direct contact, heats the iron nearly to its own temperature, a process which is completed as the metal passes through the layer of slag on top of the iron in the hearth.

The cinder requires not only to be heated up to its temperature of fusion, but far enough beyond this point to give it sufficient fluidity and consequent activity to remove the sulphur coming from the coke, and permit the dissolved oxide of iron to separate out.

So long as sufficient heat is produced in the hearth to impart to the cinder the temperature necessary to give this fluidity, the iron oxide is reduced and separates out; the cinder remains bright; and silicon can be reduced and can stay in the iron, making it gray. But when the temperature required is so high that sufficient heat for this purpose is not furnished in the hearth, the cinder becomes too thick and viscous to permit the operations mentioned; the oxide of iron remaining in it makes it black and, acting as a powerful oxidizer, prevents silicon from going into the iron.

This condition may arise in any one of three ways: (1) By an increase in the lime-content of the slag, raising its fusion-temperature; (2) by a reduction in the quantity of available heat, due to decreased temperature of the blast or increase of moisture; or (3) by a slip, bringing down into the hearth a quantity of improperly digested material.

It thus becomes evident that the temperature necessary, not only to melt the cinder, but to make it sufficiently fluid to perform its functions properly, is the "critical temperature," since the slag and iron must be brought to this temperature, and the final reduction of the ore must be performed above it (and, most probably, other reactions). What may for convenience be called the free-running temperature of the cinder is therefore taken in this paper as the critical temperature.

FACTS OF PRACTICE EXPLAINED BY THE CRITICAL TEMPERATURE

One of these is the fact that furnaces working on rich ores do not commonly show the low fuel-consumption as compared with those working on siliceous ores, which might be expected in view of the large quantity of heat required to melt the slag. The explanation seems to be that in smelting the richer ores the much smaller slag-volume available for carrying off sulphur, requires a much more calcareous slag, and therefore a higher critical temperature, which reduces the available heat per pound of fuel enough to offset largely the advantage of having less slag to melt.

The extremely low fuel-consumption of charcoal furnaces furnishes an illustration of the opposite kind. Having practically no sulphur in the fuel to contend with they can run on a very siliceous and fusible cinder, so that their critical temperature is several hundred degrees lower than that of coke furnaces smelting the same ore—which largely increases the amount of available heat.

The fuel-consumption of furnaces making ferromanganese is, on the other hand, out of all proportion to that of iron furnaces in view of the fact that the heat required for the reduction of MnO_2 is only 25 per cent more than for that of F_2O_3; but this again becomes explicable when we consider the temperature necessary in the two cases, which, though not definitely known, is known to be much higher for manganese than for iron. In the case of iron, nearly all the reduction is effected before the charge reaches the critical temperature; but with manganese this is far from being the case. The quantity of "available heat" required is therefore much higher, as well as the temperature of its application, and the fuel consumption per pound of manganese is therefore much greater.

Similarly the fuel-consumption in the production of iron with 3.5 per cent silicon is probably at least 20 per cent greater than that required for 1.5 per cent silicon iron, though the difference in the heat actually required for its reduction is only 7 per cent. But the silicon cannot be reduced at all except at high temperatures and the critical temperature is therefore raised, as well as the quantity of heat required above it, so that the fuel-consumption is augmented in correspondingly higher ratio.

It is interesting in this connection to consider why in order to make high-silicon iron with a reasonable fuel-expenditure a small hearth is necessary. The reason probably is that since the necessary high temperature cannot be secured by the use of calcareous slag (because such a slag does not allow the silica to leave it and be reduced to silicon) it can only be secured by a longer exposure of the charge to the products of combustion, and for this purpose the currents of both gas and dripping iron must be of smaller cross section, thereby virtually lengthening them and increasing the number and duration of the contacts of the dripping iron with the incandescent fuel—the condition most favorable to the reduction of silicon and its absorption by the iron.

If the claim here made for the existence and position of a "critical" temperature be admitted, it follows that the attainable economy of fuel is subject to a double limitation: (1) By the total development of heat produced in the furnace per pound of fuel, and (2) by the proportion of this heat available above the critical temperature.

A legitimate corollary to this proposition is, that the work done in the process may be divided into two parts, that done below the critical temperature and that done above it, corresponding approximately to the work done above the zone of fusion and that done below it, or, roughly, to that done in the shaft of the furnace and that done in the bosh and hearth. We may for convenience call these respectively the preliminary and the final work. The total heat introduced into and developed in the furnace being H_t and the part expended in the bosh and hearth in the final work being H_a (the "available" heat), the heat necessary for the performance of the preliminary work is $H_t - H_a$.

From the investigations of Bell and others we know with considerable accuracy the total quantity of heat required for the production of a unit weight of pig iron, and from the diagrams herewith given we can determine approximately the proportion of this which must be applied above the critical temperature. In view of the preceding discussion it is apparent that there must be a reasonably definite ratio between these two quantities or between the latter and their difference—in other words, between H_a and $(H_t - H_a)$.

This can be put in the form of an equation which will help to make the matter clear.

If we call the total heat required to produce a unit of

iron R_t, and the fuel required per unit of iron (calculated on this basis) n_1 (H_t being, as before stated, the total heat developed in the furnace by the unit of fuel), we have

$$\frac{R_t}{H_t} = n_1 \qquad (A)$$

or $R_t = n_1 H_t$, the equation, of which both sides were so magnificently and completely analyzed by Bell.

If, however, we denote by R_a the heat required, above the critical temperature, per unit of iron produced, H_a being the available heat and n_2 the fuel-consumption determined on this basis, we have

$$\frac{R_a}{H_a} = n_2 \text{ or } R_a = n_2 H_a \qquad (B)$$

Both A and B must be satisfied if the reduction is to be complete.

If we should increase the degree of oxidation of the fuel, and thus increase H_t without affecting H_a we would effect no fuel economy since we should do the preliminary work upon a larger quantity of ore than the available heat could take care of in the bosh. The furnace would consequently become cold and an increased qnantity of fuel would have to be used to make good the deficiency in available heat.

If, on the other hand, we increased the available heat H_a without increasing the total heat H_t we should either change the grade of the iron enough to absorb the heat-excess or drive the heat up to the higher zones of the furnace, with those disastrous results which furnacemen know under the caption "too hot and sticking." But no fuel would be saved because no more heat being produced for the preliminary work no increase in the quantity of ore prepared for final reduction could take place, hence no increase of output for the same fuel.

It is thus seen that it is necessary to increase the two quantities of heat in the same ratio if any economy is to be achieved. Here the quotation from my former paper ends. It should be particularly noted that, as mentioned above, the mere conception of a critical temperature without determining what this temperature is and what controls it, is of little use and the determination that it depends upon the free-running temperature of the slag is almost as important and as useful in understanding the action of the furnace as the conception of the critical temperature itself.

In fact, the French metallurgist, M. A. Lodin, published in *Comptes Rendus*, Nov. 28, 1904, a brief note suggesting the critical temperature theory to account for the results of the dry blast, but used the fusion temperature of the slag instead of the free-running temperature as the critical temperature. He did not connect it up with the hot blast or the broad facts of practice nor give any quantitative results, and the suggestion did not receive any attention, as far as known to me. My own "disclosure" of the idea was made in patent applications filed April 9, 1903 (see U. S. patent 783,-044), and my original chart of "available heats" was dated and witnessed 1902. Since that time it has become evident that the term "available heat" is too loose, since heat not "available" in the hearth and bosh passes up into the shaft of the furnace and does useful work there so becoming available. I have therefore substituted the terms "hearth heat" for this and use the corresponding term "shaft heat" for that developed or carried into the shaft.

The first requisite to making and understanding such calculations is a table of thermochemical data and specific heats and I give below tables I, II and III of these quantities taken from Prof. J. W. Richards' "Metallurgical Calculations" and where necessary converted to Fahrenheit temperatures and British thermal units instead of calories.

This excellent work had not been published at the time the calculations in the article above quoted were made and the data available to me were not as accurate as those given by Professor Richards.

I have recently recalculated the hearth heats under different conditions in accordance with these more accurate data for the chart, Fig. 1. This is substituted for the original Fig. 1, as the results it gives are the same in principle but somewhat more accurate and the range of conditions covered is wider.

It will be noticed that the chart is based on 85 per cent fixed carbon burned in the hearth which may seem strange as all good coke is much higher than this in fixed carbon. The reason is that the iron made takes up about 4 per cent of its own weight of carbon so that on the basis of a pound of coke of 89 per cent fixed carbon per pound of iron, 0.85 lb. carbon represents approximately the actual amount burned in the hearth with no solution loss, but when much of the coke is lost by solution, it is necessary to determine the actual weight

TABLE I

Element	Compound	Molecular Weight	Heat of Formation, B.t.u. Per Lb. Molecule	Per Lb. Element	Per Lb. Oxygen	Per Lb Compound
Fe	Fe_2+O_3	112+48	352,000	3,145	7,330	2,200
	F_3+O_4	168+64	487,500	2,905	7,625	2,100
	Fe+O	56+16	118,300	2,115	7,390	1,480
C	C+O	12+16	52,500	4,375	3,280	1,875
	$C+O_2$	12+32	175,000	14,750	5,470	3,980
	CO+O	28+16	122,500	CO_4,375 / C 10,400	7,650	2,790
H	H_2+O	2+16	109,000	54,500	6,530	5,806 to gas
Mn	$Mn+O_2$	55+32	226,000	4,110	7,060	2,600
	Mn_3+O_4	165+64	591,000	3,580	9,250	2,680
	Mn+O	55+16	163,600	2,985	10,230	2,308
Si	$Si+O_2$	28+32	324,000	11,580	10,130	5,400
P	P_2+O_5	62+80	657,500	10,600	8,210	4,630
Ca	Ca+O	40+16	236,600	5,910	14,780	4,220
	(Ca+O)+(C+O_2)	40+12+48	493,000	.....	.....	814
Mg	Mg+O	24+16	258,000	10,740	16,130	6,450
	(Mg+O)+(C+O_2)	24+12+48	486,000	.....	.....	662

TABLE II—SPECIFIC HEATS OF GASES

Substance	Temp. Range F	Specific Heat Per Lb.	Per Cu Ft.	Volume of 1 Lb. in Cu. Ft.	Weight of 1 Cu. Ft. in Lb
H	0°–3,600°	3.37+ 0.00017t	0.0189+ 0.0000009t	178.23	0 00561
O	0°—3,600°	0.2104+ 0.0000104t	0.0189+ 0.0000009t	11 209	0 0892
N	0–3,600°	0.2405+ 0.0000119t	0.0189+ 0.0000009t	12.752	0 0784
CO	0–3,600°	0.2405+ 0.0000119t	0.0189+ 0.0000009t	12 804	0 0781
CO_2	0–3,700° F	0.19+ 0.00006t	0.023+ 0.000008t	8 102	0 1234
Air	.....	0.234+ 0.0000111t	0.0189+ 0.0000009t	12 387	0 0807
CH_4	.....	0.5929 "Kent"	..	22.301	0 04488
Carbon	0°482° F.	0.1567+ 0.0002t	.	Gas 29.85	0 0335
Carbon	482° to 1,832°	0.2142+ 0.00009t	. . .	. . .	..
Carbon	Over 1'832°	$.5=\frac{216}{t}$			
H_2O Gaseous	Up to 3,600°	0.42+ 0.000103t	0 021+ 0 000005t	. .	. ...

Table III—Specific Heats, Etc., Solids

Substance	Temperature Range F	Sm.	Melting Point	Latent Heat Fusion, B.t.u
SiO_2	0-$t°$	0.1833+ 0.000042t	3450°	243
CaO	(Est.)	0.1715+ 0.000004t	.....	.....
MgO	Any	0.2420+ 0.00001t	.....	.....
$CaOCO_2$	68°-212°	0.2086	.....	.....
CaO, MgO } $2CO_2$	68°-212°	0.2179	.....	.....
Al_2O_3	Any	0.2081+ 0.000°486t	About 4000°	917
Fe_2O	.....	0.1456+ 0.0001t	.....	.....
t	.....	0.1447+ 0.0001t	.....	.....
eO	(Assumed)	0.1460	.....	.....
MnO	.....	0.1570	.....	.....
MnO_2	.....	0.159	.....	.....
$Mn_2O_3H_2O$	.....	0.1760	.....	.....
Silicates:				
Mg_2SiO_4	32°-212°	0.220	2550	234
$MgSiO_3$	32°-2200°	0.301	2375	207
$CaSiO_3$	32°-2200°	0.288	2280	180
$CaAl_2Si_2O_8$	32°-2200°	0.294	2230	180
$Ca_3MgSi_4O_{12}$	32°-2200°	0.264	2190	170
$CaMgSi_2O_6$	32°-2200°	0.281	2400	180

of fixed carbon burned in the hearth. The results taken from the chart can be applied to this actual weight (in pounds) by dividing by 0.85.

We shall presently revert to this matter of solution loss and its consequences at greater length.

Need often arises to figure quickly the total heat imparted to the furnace by the coke under different conditions allowance being made for the CO_2 from different proportions of limestone, for different top temperatures, and different ratios of CO to CO_2 in the top gas; for this purpose; a chart, also from "Notes on the Physical Action of the Blast Furnace," is reproduced as Fig. 2, from which this quantity may be directly taken. $L = 0$ means the condition when no limestone is charged and $L = 1$ means one pound per pound of coke, intermediate quantities can easily be interpolated by eye with sufficient accuracy. This diagram is based on a pound of fuel of 99 per cent carbon. A supplementary diagram at the top gives the heat brought by the blast for a pound of coke at different temperatures which should be added to the other for the total. This diagram saves much tedious figuring, but must be used with discretion because it takes no account of the presence of any hydrogen which is often produced by the decomposition of moisture from the charge and the oxygen from this moisture oxidizes CO to CO_2 and gives a very distorted impression of the time conditions, unless its source be taken into consideration, because the decomposition of the water absorbs almost as much heat as the corresponding oxidation of CO to CO_2 gives out.

This diagram is based on 0.9 lb. carbon while Fig. 1 is based on 0.85 lb. The discrepancy arose when Fig. 1 was recalculated, both having been based on 0.9 lb. originally; 0.85 is undoubtedly more correct, but Fig. 2 can only be used for rough approximations, and it is hardly worth while to recalculate it merely for the sake of uniformity.

(To be concluded)

The **mica** produced in the United States in 1914 was valued at $328,746.

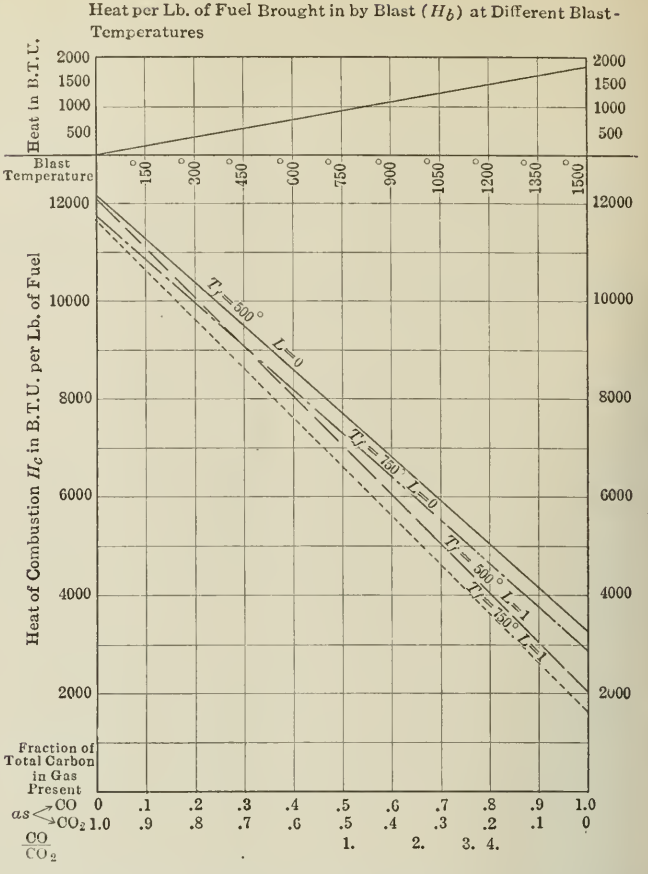

Heat per Lb. of Fuel Brought in by Blast (H_b) at Different Blast-Temperatures
Heat in B.T.U.
2000
1500
1000
500
Blast Temperature
150° 300° 450° 600° 750° 900° 1050° 1200° 1350° 1500°
Heat of Combustion H_c in B.T.U. per Lb. of Fuel
12000
10000
8000
6000
4000
2000
T_t = 500° L=0
T_t = 150° L=0
T_t = 500° L=1
T_t = 150° L=1
Fraction of Total Carbon in Gas Present as CO / CO_2
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
1.0 .9 .8 .7 .6 .5 .4 .3 .2 .1 0
CO / CO_2
1. 2. 3. 4.

FIG. 2—DIAGRAM SHOWING HEAT IMPARTED TO STOCK BY COMBUSTION IF 1 LB. OF FUEL (90 PER CENT C.) WITH DIFFERENT RATIOS OF CO TO CO_2. TOP TEMPERATURES AND WEIGHTS OF LIMESTONE PER LB. OF FUEL, ALSO (ABOVE) HEAT BROUGHT IN BY BLAST, H_b.

The Stark Rolling Mill Co. of Canton, Ohio, maker of "Toncan" metal has sent us a booklet on "Corrosion, the Cause, the Effect, the Remedy," and also a small booklet entitled "The Sheet Metal Primer."

Testing of Rubber Goods.—Circular No. 38 of the Bureau of Standards, recently issued contains much valuable information on rubber, including the manufacture and physical testing of rubber and the chemistry of rubber.

The **International Oxygen Company** is erecting an oxygen and hydrogen generating plant at Verona, Pa., in the Pittsburgh district, for the accommodation of its customers in that vicinity. This new factory will also serve as a demonstrating installation of the I. O. C. system for inspection by the rapidly increasing number of heads of industries who are deciding to secure the economies resulting from the production, in their own shops, of their required oxygen and hydrogen. Mr. Phillip J. Kroll will be manager of this branch.

Awards for Heat Insulating Material.—The Superior Jury of Awards at the Panama-Pacific International Exposition, San Francisco, has awarded a Grand Prize to the nonpareil heat-insulating materials for general excellence. These materials are manufactured by the Armstrong Cork & Insulation Company, Pittsburgh, Pa., and include nonpareil insulating brick for industrial furnaces, ovens, boiler settings, kilns, etc., nonpareil high-pressure steam covering for high pressure and superheated steam lines, feed-water heaters,, etc., nonpareil cork covering for drinking water systems, brine and ammonia lines and all cold pipes, and nonpareil corkboard for cold storage rooms.

A New Electrolytic Method of Sewage Disposal*

BY J. C. OLSEN

(*Concluded from page* 739)

EXPERIMENTS USING LIME AND CURRENT

The first series of experiments were carried out for the purpose of ascertaining the effect of the operation of the machine with the addition of lime on the character of the sludge and the effluent. The machine was operated under what may be termed normal conditions. Lime was introduced into the sewage before passing through the machine in quantities equal to 1000 to 1300 lb. per 1,000,000 gal. which is equivalent to 7½ to 9½ grains per gallon. The quantity of lime used was ascertained by the tank being filled with milk of lime of known strength. Titrations were also made of the effluent to ascertain the amount of calcium oxide present in excess over that required to react with the dissolved carbonic acid and the alkalinity of the sewage. The current varied in different tests and ranged from 19.5 to 40.9 amp. This amount of current represented a range of 22.5 to 44.7 coulombs per liter treated (85 to 169 coulombs per gallon). This quantity of electricity will liberate theoretically from 0.00174 to 0.00332 gram per liter or 1.21 to 2.31 c.c.

Samples were taken of the raw sewage designated as "A," of the inflow to the sedimentation tanks designated as "B," and also of the effluent from the sedimentation tank designated as "C." Several samples designated as "D" were also taken of the outfall into the stream at a point several hundred feet distant from the buildings of the plant. These samples were used for the determination of physical appearance, chemical composition, count of bacteria, dissolved oxygen and putrescibility. Samples of sludge were also taken from time to time for examination with reference to putrescibility.

Table I gives the average of a considerable number of analyses of the samples taken at the four points indicated.

TABLE I.—AVERAGE OF THE ANALYSIS OF RAW AND PURIFIED SEWAGE BY ELECTROLYTIC PROCESS

	Raw Sewage	Purified Sewage		
		Before Sedimentation	After Sedimentation	
	Sample *A*	Sample *B*	Sample *C*	Sample *D*
Nitrogen as				
Nitrites	0	0.84	0.13	
Nitrates	0.02	2.22	3.8	
Free ammonia	26.5	20.0	13.6	
Total organic nitrogen	13.8	9.2	5.5	
Oxygen				
Dissolved	1.62	2.92	3.94	8.35
Per cent of saturation	13.89	26.59	38.38	80.11
Consumed	42.8	36.4	20.7	
Turbidity	41	27	7.2	
Color	47	37	19	
Chlorine	67.6	71.2	70.5	
Carbon dioxide	21.28	0	0	
Calcium oxide	0	128.3	80.3	
Alkalinity	291.7	174.4	80.75	
Calcium carbonate		294.8	95.3	
Bacteria count by agar	288,000	46,256.5	471	169

The amount of oxygen liberated by the electric current was relatively small. It ranged from 1.74 to 3.32 mg. per liter of sewage treated which is equal to 1.21 to 2.31 c.c. per liter.

It will be noted that the percentage of nitrates increase from 0.02 in the raw sewage to 2.22 in sample B and to 3.8 in sample C, which indicates oxidation of the nitrogen of the sewage.

The percentage of ammonia decreased from 26.5 to 20 and 13.6 respectively in samples B and C. Undoubtedly, ammonia is lost both by oxidation and volatilization.

The percentage of organic nitrogen decreased from 13.8 in the sewage to 9.2 in sample B. This disappearance of organic nitrogen is, no doubt, partly due to oxidation brought about by the anodic oxygen and partly to precipitation by the lime in the sludge as it was found to contain a considerable amount of nitrogen. The decrease in organic nitrogen continues between B and C which is probably due partly to further precipitation in the sludge and partly to further oxidation. In this manner 60 per cent of the organic nitrogen is removed from the sewage. This large reduction of the organic nitrogen is an important factor in this method of sewage purification.

The oxygen consumed decreases from 42.6 to 26.4 to 20.7 which indicates removal of a large proportion of the dissolved and suspended organic matter.

The per cent of saturation of dissolved oxygen increases from 13.89 to 26.59 and 38.38 which is a total increase of 34.49 per cent.

The bacteria count decreased 84 per cent between A and B, and 99.83 per cent between A and C, which indicates a high degree of purity in the effluent.

A considerable amount of the organic matter is no doubt precipitated with the lime in the sludge and this accounts for some of the changes noted. A considerable number of the bacteria are no doubt removed in this manner. The flocculation and precipitation of the sludge is very rapid after electrolysis and is much more rapid and complete than when lime only is used. This is probably due to the fact that the organic matter in the sewage is present as a colloidal solution which the electrolysis precipitates.

A comparison of the composition of sample C (which was taken after sedimentation, which, in this plant, occupied about 4 hr.) with samples B and A shows that the differences noted between A and B have become more pronounced, that is, nitrates, dissolved oxygen and free lime continue to increase; an exception is found in nitrites which decrease. The remaining constituents decrease in quantity, namely: Ammonia, organic nitrogen, turbidity, color, alkalinity and bacteria. Carbon dioxide naturally remains absent in the presence of free lime. The increase in free lime and decrease in alkalinity is due to the fact that the reaction between the lime and the calcium bicarbonate and other alkaline salts in the sewage requires several hours for its completion and that it is for a time supersaturated with respect to some of the salts formed. The ammonia, no doubt, slowly volatilizes and considerable amounts of atmospheric oxygen are absorbed during sedimentation. The reduction in turbidity and color is, no doubt, due to precipitation.

A number of tests were made on the overflow from the sedimentation tank (sample C) after it had passed through a pipe several hundred feet long and was discharged into a stream flowing from the plant. The time required for this flow was estimated to be about 15 min. The dissolved oxygen rose from about 40 per cent to about 80 per cent while the bacteria count fell from 471 to 169. These results indicate the great purity of the effluent. There could not be any readily oxidizable organic matter in a water which will absorb oxygen so quickly and hold 80 per cent of its saturation value. The drop in bacteria content points to the same conclusion. This was confirmed by allowing samples of this effluent to stand in the laboratory and making bacteria tests on succeeding days. The bacteria count steadily decreased for as long as 9 days.

Table II.—Stability of Effluent from Electrolytic Process

As Represented by the Number of Bacteria per C.C. After Plating on Agar

A	B	C	D
	At time of taking sample		
	3	170	
	After standing 24 hours		
	0	21	
	At time of taking sample		
	30,000	400	
	After standing 2 days		
	1,820,000		
	After standing 9 days		
		37	
	At time of taking sample		
550,000			103
	After standing 4 days		
620,000			24

The quantity of lime added varied considerably during the course of the investigation, the average being about 1300 lb. of hydrated lime (72 per cent CaO) per million gallons. This is equal to about 113 parts calcium oxide per million or 6.6 grains per gallon.

A considerable proportion of this lime reacted with the free carbon dioxide in the sewage and then with the calcium bicarbonate, forming calcium carbonate, which constituted a large part of the flocks which settled and formed the sludge. The excess remained as free calcium hydroxide in the effluent. Considerable time was required for the completion of these reactions as was shown by adding lime to a sample of the sewage and titrating with standard acid using phenolphthalein and methyl orange as indicators.

Not only does the reaction seem to be slow but the liquid seems for a time to be supersaturated with calcium carbonate.

Tests were made with no lime at all and a considerable number of proportions up to an excess of nearly 200 parts per million of calcium oxide. When no lime was used and electrolysis only, very little purification of the sewage resulted as shown by bacteria count and clarification and flocculation. Table III gives the result of electrolysis of the sewage with a very small amount of lime as indicated by the alkalinity and absence of calcium oxide. The small amount of nitrates and oxygen consumed and large amount of organic nitrogen and oxygen consumed indicate only slight purification which is also shown by the high bacteria count.

Table III.—Analysis of Raw Sewage and Sewage Purified by Electrolytic Process

Electrical Data

Number of electrolyzing elements in series, 31; amperes, 32; volts, 102

Chemical Analysis

Results given in parts per Million

	Sample *A*	Sample *B*
Temp., degrees C.	11	11¼
Nitrogen as		
Nitrites	0.00	1.1
Nitrates	0.06	0.44
Free ammonia	26	22.4
Total organic nitrogen	26	14.4
Oxygen dissolved	2.82	3.5
Per cent of saturation	25.45	31.75
Consumed	74	48
Turbidity	55	35
Color	50	35
Chlorine	64	54
Carbon dioxide	25.0	0
Calcium dioxide	0	0
Alkalinity	291.6	314
Bacteriological Examination		
Bacteria per c.c.		
Agar	584,000	272,000
Gelatine	1,100,000	846,000
Acid-forming bacteria	55,000	45,000
B. Coli	1-100+	1-10+

On the same day using the same sewage a test was made in which the excess lime was forty-three parts per million. Very much better chemical and bacterial purification was obtained as indicated by Table IV.

Table IV.—Electrical Data

Number of Electrolyzing Elements in Series, 38; Amperes, 27; Volts, 125

Chemical Analysis

Results Given in Parts per Million

	Sample *A*	Sample *B*
Temp., degrees C.	11	11¾
Nitrogen as		
Nitrites	0.00	0.24
Nitrates	0.06	4.4
Free ammonia	26	20.0
Total organic nitrogen	26	10.0
Oxygen dissolved	2.82	4.6
Per cent of saturation	25.45	37.90
Consumed	74	55
Turbidity	55	17
Color	50	35
Chlorine	64	75
Carbon dioxide	25.0	0
Calcium oxide	0	43.1
Alkalinity	291.6	101.0
Bacteriological Examination		
Bacteria per c.c.		
Agar	584,000	6,010
Gelatine	1,100,000	140,000
Acid-forming bacteria	55,000	2,000
B. Coli	1-100+	1-1 + 1-10+

A still higher degree of purity was obtained by using an excess of lime equal to 236 parts per million as shown by Table V.

Table V.—Electrical Data

Mean rate of sewage flow, gals. per day	760,000
Electrolyzing elements in series	38
D. C. average volts	105
D. C. average amperes	22
Anodic oxygen (theoretical) gramme, per liter	0.00208
Anodic oxygen (theoretical) c.c., per liter	1.448

Chemical Analysis

Results Given in Parts per Million

	Sample *A*	Sample *B*	Sample *C*
Temp., degrees C.	13	13.5	13.3
Nitrogen as			
Nitrites	0	0.04	0.10
Nitrates	0	2.4	3.6
Free ammonia	26	20	12.0
Total organic nitrogen	14	5.6	0.0
Oxygen dissolved	0.4	2.46	6.11
Per cent of saturation	3.73	23.49	68.01
Consumed	34	20	8
Turbidity	55	2	3
Color	70	25	15
Chlorine	65.5	122	80
Carbon dioxide	24.8	0	0
Calcium oxide	0	236	162
Alkalinity	277.8	.....	.....
Calcium carbonate	.....	239	96
Bacteriological Analysis			
Bacteria per c.c.			
Agar	160,000	0	5
Gelatine	1,000,000	0	170
B. Coli	1-1000+	1-10-	1-1-

This high purity was obtained in spite of the fact that the amount of current used was equivalent to only 1.448 c.c. of anodic oxygen per liter.

The effect of the electric current in increasing flocculation and purification of the sewage is strikingly shown in the following experiment.

At the time of starting the experiment the machine was running normally and had been so for several days, current, lime and agitation being employed. The effluent was clear and excellent in every respect. The lime was added at the far or outlet end of the machine.

Sewage flow, 755,000 gals. per day.

Current, 40 amp., 120 volts.

About 1000 lb. of hydrated lime (72.87 per cent calcium oxide) being used per day. This is equivalent to 965 lb. of lime per million gallons, or 9 grains of lime per gallon.

Under these normal conditions the appearance of the liquid in the flume was good, with large flocks, which

settled rapidly in the Imhoff tube, leaving a clear liquid above. The Imhoff reading was 20 c.c. (All Imhoff tube readings were made after ten minutes' sedimentation.) The final effluent was nearly water-like in appearance, odorless and there was no odor in the tankhouse or plant generally.

1.50 p. m.—The current was cut off, and the agitation by means of the paddles stopped. The flow of milk of lime into the sewage at the outlet end of the machine was continued.

1.55 p. m.—The liquid in the flume had become very noticeably darker, with much smaller flocks.

2 p. m.—The liquid in the flume was decidedly dark, the flocks small. Imhoff tube reading, 3 c.c.

2.02 p. m.—The current was turned on again, other conditions remaining the same.

2.07 p. m.—The liquid in the flume was lighter and the flock better.

2.12 p. m.—The liquid in the flume same as at 2.07 p. m. A half gallon was lighter in color than a similar sample at 2. Imhoff tube reading, 10 c.c.

2.17 p. m.—The point of lime feed was changed, so as to allow the lime to be admitted at the suction end of the pump, thereby being mixed with the sewage which then passed through the machine. The current was turned off, and there was no agitation by means of the paddles.

2.22 p. m.—The liquid in the flume was darker, and the flocks smaller.

2.31 p. m.—The liquid in the flume still dark, the flocks small and poor. In the Imhoff tube, the flocks appeared small and poor. Imhoff tube reading 0.75 c.c.

2.32 p. m.—The electrolyzing current was again turned on and agitation by means of the paddles started. The lime continued to be added through the pump.

2.42 p. m.—Color dark in the flume, but flocculation better.

2.46 p. m.—Imhoff tube reading, 16 c.c., but the sediment was dark in color.

2.47 p. m.—The electrolyzing paddles and current continued in operation but the lime was introduced at the outlet end of the machine. This reproduced the conditions found at 1.30 p. m.

2.52 p.m.—The liquid in the flume became lighter, with a heavy flock, quickly settling. The deposit in the Imhoff tube was heavy, and settled rapidly.

This experiment, together with the one previously made, showed that electrolyzation of the sewage serves to produce a lighter colored effluent, and materially increases the amount of flocculation and precipitation of the suspended matter in the sewage, probably because the current tends to agglutinate the colloidal particles.

The chemical analyses of the effluent show that when the current and lime are both used the effluent is more free from nitrogenous organic matter, 60 per cent of the total organic nitrogen being removed; whereas when the current is not used only 11 per cent of the nitrogenous organic matter is removed and the bacteria multiply in the effluent, probably because of the greater abundance of food.

In order to secure information as to the effect of lime only on the Elmhurst sewage, a number of experiments were carried out in which conditions were identical with the electrolytic treatment except the electrolyzation. Table VI gives the average of these results.

It will be noted on reference to the results given in Table VI that the percentage of nitrates in sample B is very small and differs in this respect from the corresponding average in the electrolytic treatment (Table I). In sample C (Table VI), however, the percentage

TABLE VI.—AVERAGE OF THE ANALYSES OF RAW AND PURIFIED SEWAGE WITH LIME ONLY, WITHOUT ELECTROLYZATION

	Sample *A*	Sample *B*	Sample *C*
Nitrogen as			
Nitrites		0	0.32
Nitrates		0.02	3.6
Free ammonia	22	15.8	10.0
Total organic nitrogen	3.6	3.4	3.2
Oxygen dissolved	2.92	3.78	4.80
Per cent of saturation	27.75	36.25	46.07
Consumed		23.7	21.0
Turbidity	50	33	10
Color		45	14
Carbon dioxide	24.62	0	0
Calcium oxide	0	19.6	9.52
Alkalinity	271.8	299.6	112.1
Calcium carbonate	0	271.2	86.61
Total solids			131
Bacteria per c.c.			
Agar	187,000	54,120	5430

of nitrates is 3.6 which is very nearly equal to the corresponding average in Table I.

The organic nitrogen decreases from 3.6 to 3.4, which is a reduction of only 6 per cent compared with 40 per cent in the table of electrolytic treatment (Table I). Between B and C there is a further decrease of only 6 per cent compared with 20 per cent in the table of electrolytic treatment. This indicates an important difference between these methods of treatment and shows that the removal of organic nitrogen is comparatively slight in the case of treatment with lime alone.

The total increase in percentage of dissolved oxygen between samples A and C is 18.32 per cent as compared with 24.49 in the case of the electrolytic treatment. The decrease in bacteria count between A and C is 9.7 per cent as compared with decreases of 84 and 99.83 per cent respectively in the case of the electrolytic treatment.

The most striking evidence of the very marked purifying effect of the treatment with lime and electrolyzation is obtained by noting the change in bacteria content on allowing samples to stand for one or more days. These results are given in Table II.

TABLE VII.—STABILITY OF SEWAGE AND EFFLUENT WHEN USING LIME ONLY
Represented by the Number of Bacteria per C.C. Incubated on Agar

A	*B*	*C*	*D*
	At time of taking sample		
140,000	51,000		
	After standing 8 days		
120,000	77,000		
	At time of taking sample		
	10,000		
	After standing 3 days		
	1,540,000		
	At time of taking sample		
124,000	10,000	7,400	
	After standing 1 day		
1,860,000	4,032,000	750,000	
	After standing 2 days		
520,000	2,670,000	591,000	
	After standing 3 days		
820,000	338,000	105,000	

It will be noticed that the bacteria increase very rapidly after treatment with lime only. In this respect there is a very striking difference when samples which have been subjected to electrolysis and lime are allowed to stand. In this case there is a very marked decrease in the already low bacteria count. An exception to this condition is sometimes found in sample B which has not passed through the sedimentation tank.

The difference between the two processes is also very noticeable on an inspection of sewage disposal plants operated by the two methods. At plants using lime only the effluent is dark colored, quite high in bacteria and far from pure. Both effluent and sludge produce considerable odor so that the disposal works are a nuisance to nearby neighbors while the effluent pollutes streams into which it is discharged.

On the other hand the Elmhurst plant during the time it has been operating on 750,000 gal. of sewage has been entirely free from unpleasant odor, the effluent being clear and free from color and could be discharged

into any stream without causing any pollution whatever.

It is common, when discussing electrolytic processes for sewage treatment, to speak of the liberation of chlorine, or the formation of a hypochlorite by the action of the electric current upon the common salt present in the sewage, and then to credit such substances with much of the beneficial action claimed for the process. Careful chemical examination made at various times of the effluent of the electrolytic machine at Elmhurst failed to give any reaction whatever for free chlorine or hypochlorites. The conclusion seems warranted that neither of these substances is present in the sewage electrolyzed by the process.

In order to confirm this conclusion, a study was made of the effect of adding bleaching powder to sewage. A visit was first made to Providence, R. I., where lime and bleaching powder have been used for a great many years in the treatment of the municipal sewage. At the Providence plant 144 lb. of bleaching powder and 400 lb. of lime are used per million gallons of sewage treated. The amount of bleaching powder added is 17.3 parts per million, the available chlorine being 5.7 parts per million. This is equivalent to 1.3 mg. of oxygen per liter which is about the amount of anodic oxygen produced by the electric current in the Landreth machine. At Providence the treated sewage is allowed to settle in sedimentation tanks.

The effluent as discharged into the river contains from 20 to 50 per cent of dissolved oxygen. The dissolved oxygen in the river is generally zero. Sixty-five per cent of the total bacteria were removed, as counted on litmus agar, incubated at 37½ deg. The B. Coli removed amounted to 97 per cent. The effluent is putrescent and quite impure, but the use of the process is justified by the polluted condition of the river, so that the requirements for purity are very low. The statement was made that if it should become necessary to secure a higher state of purity, a more efficient process of sewage disposal than the one now in use must be installed.

Laboratory tests were made with Elmhurst sewage. Bleaching powder and lime were added in the proportions used at Providence, namely, 144 lb. of the former and 400 lb. of the latter. The odor of hypochlorites was very noticeable and persisted for about 24 hr. No odor of this kind had ever been detected on the effluent at Elmhurst. The sewage also remained turbid and did not settle clear even after several days' standing.

The bacteria count was reduced about 97 per cent, but on standing 21 hr. the bacteria count had risen and was higher than that of the raw sewage. The odor of chlorine had also disappeared, showing that the bleaching powder prevented the growth of bacteria but did not remove the organic matter and produce a stable effluent. The results are given in Table VIII.

Another test was made in which twice as much lime and bleaching powder was added as used at Providence. This would give chlorine equivalent to about 2.6 mg. of anodic oxygen per liter, which, with the amount of lime used, would give a very clear and stable effluent by the Elmhurst electrolytic process. In this experiment the chlorine odor persisted for 24 hr., the bacteria count was very low on the second day but after standing for three days, the bacteria count on agar was 5,550,000 and the liquid had a putrid odor. The results are given in Table IX.

In another test the untreated sewage as well as the treated sewage was allowed to stand and was plated. After five days the bacteria count was 4,460,000 in the sewage treated with bleaching powder. The results are given in Table X.

Table VIII—Bacteria Per C.C. in Raw Sewage and Sewage Treated with Lime, and Bleaching Powder

Bleaching Powder Added, 144 Lb. Per Million Gal. Lime Added, 400 Lb. Per Million Gal.

	Raw Sewage	Treated Sewage	Odor
After standing 1 hour			
Agar	62,000	1,830	Chlorine
Gelatine	520,000	22,000	
After standing 21 hours			
Agar	.....	907,000	Quite putrid
Gelatine	.....	2,430,000	
After standing 3 days			
Agar	.....	1,800,000	Very putrid
Gelatine	.....	2,000,000	

Table IX.—Bcateria Per C.C. in Raw Sewage and Sewage Treated with Lime and Bleaching Powder

Bleaching Powder Added, 288 Lb. Per Million Gal. Lime Added, 800 Lb. Per Million Gal.

	Raw Sewage	Treated Sewage	Odor
After standing 1 hour			
Agar	62,000	200	Chlorine
Gelatine	520,000	4,200	
After standing 24 hours			
Agar	.....	200	Slight Chlorine
Gelatine	.....	160	
After standing 3 days			
Agar	.....	5,500,000	Putrid
Gelatine	Plates entirely liquefied		

Table X.—Bacteria Per C.C. in Raw Sewage and Sewage Treated with Lime and Bleaching Powder

Bleaching Powder Added, 235 Lb. of 23 Per Cent Chlorine Per Million Gallons, Which is Equivalent to 63 Lb. of Chlorine Per Million Gallons or 6.5 Parts Chlorine Per Million Gallons. Lime Added ,1079 Lb. Calcium Oxide Per Million Gallons

	Raw Sewage	Treated Sewage
After standing 3 hours		
Agar	580,000	130
B. Coli	.....	0
After standing 24 hours		
Agar	.....	230
B. Coli	.....	0
After standing 48 hours		
Agar	300,000	50
B. Coli	.....	0
After standing 3 days		
Agar	610,000	40
After standing 4 days		
Agar	620,000	.....
After standing 5 days		
Agar	.....	4,460,000
B. Coli	.....	0

It is apparent from these results that bleaching powder has a very marked destructive action on bacteria but that there is very little action on the dissolved organic matter. It is, no doubt, very effective in purifying a contaminated water but is not a suitable reagent for the oxidation of the large amount of organic matter present in a sewage so as to produce a stable effluent.

The sludge produced at Elmhurst amounted to about 1500 lb. of the dried material. The moist press-cake contained about 69 per cent of water. It contained about 0.59 per cent ammonia equal to 3.7 per cent proteid and 0.54 per cent calcium phosphate, the remainder being mostly calcium carbonate. While moist the press-cake has a slight odor of ammonia which becomes more

intense if the sludge is kept in a closed vessel. Putrescibility tests showed it to be stable for more than four days. When allowed to dry, it becomes entirely odorless. A number of methods of disposal of this sludge seem to be feasible. It can be used as a filler on low ground as it will not produce a nuisance. If used in this manner, filter pressing would be unnecessary if vacant ground near the plant is available as the liquid sludge could be pumped out. The sludge would also find some use as a fertilizer. It could also be burned so as to recover the lime.

COST OF OPERATION

A careful study was made of the cost of operation of this process of sewage disposal. The actual cost of operation of the Elmhurst plant cannot be taken as the normal operating cost of a plant of this kind because the plant was designed and built for an entirely different process and because during the period of the test it was not continuously operated on a normal basis. The operating cost will include the following items: electric current and power, lime, labor, maintenance supplies, etc., and sludge.

ELECTRIC CURRENT AND POWER

From the study made of the process a fairly accurate estimate may be made of the minimum amount of electric energy required for the electrolyzation of a million gallons of sewage and this was found to be 85 kw.-hr. The cost of electric current varies greatly in different localities. At 2 cents this item would be $1.70 per million gallons.

Electric energy was also used to rotate the paddles and produce agitation in the machine. This required 60 kw.-hr. per million gallons, and at 2 cents would be $1.20.

A small electric motor was used to operate the agitator in the lime vat and consumed 16 kw.-hr. which at 2 cents would be $0.32.

LIME

It was possible to make a very close estimate of the amount of lime required which was about 950 lb. of calcium oxide or approximately ½ ton of commercial lime. Under favorable conditions lime can be obtained in carload lots at about $6 per ton, making this item of cost $3 per million gallons.

LABOR AND SUPERVISION

It has been very difficult to estimate the cost of labor and supervision for a plant of this kind from the experience at the Elmhurst plant. This element of cost will decrease very rapidly with the size of the plant and will also vary with the method of sludge removal employed. For a 10,000,000-gal. plant $3 per million gallons would seem reasonable.

MAINTENANCE AND SUPPLIES

The principal item of expense under this heading will be the renewal of the iron electrode plates. This and other items would be covered by an allowance of $1 per million gallons.

SLUDGE DISPOSAL

The cost of sludge disposal would vary with local conditions and especially with the methods of disposal which may be utilized. The simplest and cheapest method of disposal consists in pumping the liquid sludge on the land adjoining the plant which must be filled in. The cost of pumping the sludge obtained from a million gallons of sewage is very small. If the sludge is used for fertilizer it must be filter-pressed. This will cost about $2.50 per million gallons of sewage. In a farming section the filter-pressed sludge will be removed by the farmers. Where this is not feasible the sludge must be disposed of by removal and dumping on waste land or at sea. Where this is necessary the cost may be considered $2.50 per million gallons of sewage.

TABLE XI.—ESTIMATED COST OF SEWAGE DISPOSAL BY ELECTROLYTIC PROCESS FOR A TEN-MILLION-GALLON PLANT

Lime, 5 tons at $6.00 per ton	$30.00
Electricity for electrolyzation at 2c	17.00
Electricity for agitation at 2c	14.20
Labor and supervision	30.00
Maintenance and supplies	10.00
Sludge disposal	25.00
	$126.20
Cost per million gallons	$12.62

ADVANTAGES OF THE METHOD

The advantages of the method may be briefly stated as follows:

(a) The effluent is of a very high degree of purity and may be discharged into any water course without creating any nuisance whatever or injury to fish or oysters.

(b) No odor or other nuisance is produced by the plant so that it may be located at any sewer outlet or other convenient point.

(c) The amount of space required for the plant is very small. This very much reduces the cost of the necessary site and gives a much more general choice of location.

(d) On account of the freedom from nuisance and small space required, plants may be located at convenient points and the construction of costly trunk sewers obviated.

(e) The initial cost of installation is low as compared with other processes.

The Chemical Engineering of the Hardwood Distillation Industry*

BY JAMES R. WITHROW

It would require more time than we have at our disposal to go into the details of the chemical engineering of the hardwood distillation industry. General features will be pointed out, just sufficient to give a broad survey of the problems involved in plant operation.

The industrial demand which the hardwood distillation industry meets is sufficiently indicated by the mere mention of acetic acid, methyl alcohol, acetone, chloroform and formaldehyde, without burdening you with statistics of their production, consumption, exportation and importation. The number of industries and objectives in the arts which benefit by the availibility of these substances is surprisingly great, though not all of these substances are exclusively the products of this industry.

Development

The development of the industry appears to have been very simple. From the earliest times charcoal appears to have been used in the arts and especially in metallurgy.

That liquid products could be formed during the charcoal production was very early observed. Uses were gradually found for these products, and in course of time a demand was created for them, with the result that wood carbonization was largely changed in method so as to improve the yield of the desired by-products.

The historical development of this industry is one of the most interesting in the annals of industrial chemistry, because it illustrates so well the battledore and

*A paper presented in the symposium on wood distillation at the Seattle meeting of the American Chemical Society.

shuttlecock fortune of so many of these industries. So often the by-product of to-day becomes the main product of to-morrow, and the new industry, which appears the worst competitive enemy of one industry, becomes the greatest blessing of the old industry in the next decade.

The liquid products accompanying charcoal production are said to have been recovered by the ancient Egyptians and utilized by them in embalming the dead. Pliny mentions their recovery in Syria and Theophrastus in Macedonia. As chemical knowledge in those days appears to have been very limited, and engineering skill as much so. the recovery of liquid products must have been trifling, and it was many centuries before chemical knowledge made possible and the arts demanded intelligent development.

Notwithstanding the later development of the engineering as well as chemical side of the industry the essential features of primitive wood carbonization have come down practically unaltered to the present day. This primitive charcoal burning is still practised wherever wood is plentiful—in Russia, Scandinavia, Austria-Hungary, Germany (Westphalia and the Harz), New Jersey, Maryland, etc.

In spite of various uses to which they were put in early times no real appreciation of the value of the liquid substances known to be formed during carbonization of wood came until the dawn of modern chemical investigation. Lack of sufficient fundamental chemical knowledge was largely responsible for this. For instance, as early as 1658 Glauber identified the so-called "burnt-wood acid" with acetic acid, yet not until 1802 was it identified with the acetic acid of fermentation by Thenard. In 1661 Robert Boyle discovered wood-spirit in wood distillate, yet not until 1812 did Taylor notice its analogy to grain alcohol.

The true character of this "spirit" was only established after a series of investigations by Colin, Dobereiner, Gmelin, Liebig, Sweitzer, and especially Dumas and Pèligot, ending about 1835. As a result of these investigations, together with those on the composition of the wood tar and wood gas, there came an increased effort to recover such of these by-products as were suitable for use in the arts in general, as well as in the organic chemical industries that were at this time struggling for a footing upon the investigations of the great masters of our science. The first step in this revolution was the use of by-product kilns and retorts in place of the old sod-covered pits or heaps, for carbonization. It would seem that from this point, at least, the development of the industry should have been consistent and perhaps rapid, but this was not the case.

Apparently the first product to have been systematically recovered was the wood gas. This was first used in England for illuminating purposes somewhat prior to the chemical developments just mentioned. The honor, however, for the exhaustive investigation of the illuminating, heating and power value of this gas belong to the Frenchman Phillip Lebon.

The weakly illuminating wood gas was soon outclassed, however, by the development of coal gas production, and the whole hardwood distillation industry had a precarious existence during a large part of the last century, even in spite of the fact that a satisfactory method of purifying the crude acetic acid had been devised as early as 1824 by Mollerat and Jasmeyer.

The products of the destructive distillation of coal, such as coke, illuminating gas, tar and tar distillates, were sharp competitors of the wood products. Yet when the wood industry seemed about to be relegated to the primitive woods, the sudden development of the coal-tar color industry started a demand for acetic acid, methyl alcohol and acetone which has since been augmented by the demand for the same products in the production of celluloid and smokeless powder, as well as many synthetic organic substances used in pharmacy and the arts.

The demand for methyl alcohol within a few years after Perkins' discovery of aniline dyes became so great that the price was enormous. It is not surprising, therefore, that at that time in England wood was distilled with the sole object of getting wood alcohol. A like situation is said to have arisen at one time in benzol manufacture, coal having been for a while distilled with the sole object of obtaining benzol for aniline production.

These general statements regarding the development of the industry bring us to the present situation where we recover mainly the primary products—wood gas, raw liquor (pyroligneous acid), tars and oils, and charcoal. It should be noticed in passing that while most engineering skill is a matter of quite recent development, and chemical engineering is perhaps the most recently developed phase of engineering, yet it has been able reasonably to keep pace with chemical development in this industry at least, and this may be due largely to the fact that the development of engineering methods, and the understanding and fabrication of engineering materials of construction developed along with the science of chemistry and are somewhat dependent upon it.

The Problem of the Industry

Broadly speaking, the problem of the hardwood distillation industry is the complete utilization of the weight of the original wood as far as this is possible by economical chemical engineering manipulation for the production of the products which it will yield of main industrial use or value, i.e., charcoal, acetic acid and methyl alcohol.

Economical chemical engineering involves the use and sequence of such operations as will give the maximum financial return, per unit of raw material consumed, consistent with a proper balance between low cost of operation, low initial cost of plant and highest speed of turnover (processing raw material).

When wood is heated sufficiently in the atmosphere it tends to burn, of course, to residual ash, steam and carbon dioxide, for the most part. If the air is partially excluded we obtain residual charcoal and volatile products varying widely in composition, depending upon the extent of air exclusion, from the condition of almost complete combustion of volatile products to practically entire elimination of combustion or atmospheric oxidation when air is excluded as completely as possible. The problem of the industry may be met therefore by heating the wood sufficiently to carbonize it, and in such a way as to eliminate as far as possible any atmospheric oxidation of the volatile products and, at the same time handle the distillates in such a way as to minimize refining or purification difficulties.

Modern chemical engineering skill has met the conditions of reasonably efficient solution of the problem with fair success, as is shown by the extent of the industry, and without doubt will advance still further.

Every problem, however large, is merely a series of smaller sub-problems, and each of these in turn is often resolvable into still other problems. In studying the problem of any chemical industry it is natural to divide it as far as possible into

1. The nature of the demand or market for the products or objectives of the industry.
2. The chemistry involved.
3. The operations or engineering involved.

The chemistry of the hardwood distillation industry

finds its basis in the phenomena attending destructive distillation. Much more should be known about destructive distillation than *is* known. Our concern at this time, however, is with the engineering problems involved in the utilization of this chemistry. Suffice it to say in the matter of the chemistry involved, that the products of heating the wood, as is usually the case in destructive distillation, are gaseous, liquid (condensate) and solid (residual charcoal). The gas as a whole is combustible. The liquid is acid, and in two (or three) nearly non-miscible phases—tar (and oil) and dilute alcoholic acetic acid, with dissolved tar and other substances.

Chemical Engineering Operations

The engineering operations of the industry may be divided in general into four divisions.

1. Those concerned with the preliminary handling of the raw material.
2. Those concerned in the destructive distillation proper or so-called primary distillation.
3. Those concerned with the treatment of the liquid distillate or secondary distillation.
4. Those concerned with refining operations, and derived product production. The latter is not generally connected with what is known as the crude hardwood industry, and will therefore be indicated in great brevity.

The engineering operations which group themselves in these four divisions, and which are necessary for the accomplishing of the objects of the industry, are:

I.—*Preliminary Handling of Wood.*

1. Harvesting the timber—cutting, splitting.
2. Seasoning, transportation and storage.

II.—*Preliminary Distillation.*

1. Loading oven cars.
2. Charging and sealing ovens.
3. Firing ovens (distillation).
4. Condensation and fuel gas recovery.
5. Pulling ovens (discharging hot charcoal cars).
6. Cooling charcoal.
7. Pulling charcoal coolers.
8. Aging charcoal.
9. Screening charcoal—*charcoal for the market.*

III.—*Secondary Distillation (of Condensate Obtained in II,* 4).

1. Settling "raw liquor" (condensate II, 4).
2. Separation of tar (and oil) from "raw liquor" (continuous decantation).
3. Redistillation of settled tar (for further recovery of "raw liquor"). Copper or wooden stills.
4. Condensation of acid distillate (oil added to "boiled tar," water added to original "raw liquor"—condensate II, 4).
5. Redistillation of settled "raw liquor" (for further tarry-bodies elimination). Continuous copper stills.
6. Condensation of "boiled liquor."
7. "Mixing boiled liquor" with lime (neutralization).
8. Distillation of neutralized "boiled liquor" in lime-lee still (iron).
9. Condensation of weak alcohol-acetone.
10. Settling or filtering lime-lee still residue (aqueous calcium acetate).
11. Evaporation and crystallization of lime-lee residues.
12. Drying crystallized acetate of lime (sacking, weighing, analysis). *Gray acetate of lime* (80 *per cent*) *for the market.*
13. Redistillation of weak alcohol-acetone for oil separation and concentration (Burcey pans, fractionation).
14. Condensation of alcohol-acetone in fractions. *Crude* 82 *per cent alcohol-acetone for market or refinery.*

IV.—*Refining and Derived Product Manufacture.*

Alcohol.—1. Chemical treatment of crude alcohol ($NaOH$ or H_2SO_4).
2. Distillation and condensation for elimination of chemicals, etc.
3. Fractional distillation (column still).
4. Condensation with "heads and tails" elimination. *Refined methyl alcohol and acetone-alcohol for market.*

Gray Acetate.—1. Distillation with sulphuric acid or (HCl).
2. Dust elimination from vapors.
3. Condensation of acetic acid (commercial).
4. Refining by redistillation and fractionation after chemical or electrical treatment. *Refined and concentrated acetic acid for market.*

Gray Acetate.—1. Destructive distillation.
2. Dust elimination from vapors.
3. Condensation of crude acetone and oils.
4. Separation of oils from acetone.
5. Chemical treatment (alkali) for acid elimination.
6. Redistillation for "white oil" elimination.
7. Fractional distillation of acetone.
8. Condensation. *Acetone for the market.*

Each and every one of these operations calls for its own special form of apparatus or construction, and modifies to a varying extent the design and operation of the plant. They are the essential operations or chemical engineering proper which must be carried out to secure the results obtained in first class practice. There has been indicated also, in a limited way, how some of these operations must be carried out. Sufficient preliminary discussion of the development of the industry has been given to illustrate the connection which appears to have existed between the development of both chemical knowledge and engineering skill and the growth and development of this industry.

In concluding I must express my indebtedness to Mr. Edward H. French, to whom I owe my first opportunity, a number of years ago, of working upon the problems of this industry upon which he was himself engaged.

Ohio State University,
Columbus, Ohio.

More Engineering English

From the October *Bulletin of The Engineering Society* of Buffalo:

"Mr. H——, having made a vocation of this practical art of manufacture, will undoubtedly be able to learn us a way to stronger build our organization . . ."

Evidently there is room for another hyphenated profession—that of Literary-Engineer.

Magnetic Separator Pulleys.—As illustrative of the varied applications of their magnetic separator pulleys the Cutler-Hammer Clutch Co., Milwaukee, Wis., has issued Bulletin 25 describing its many uses, method of installation and principles of operation.

Molybdenite.—At the molybdenite mine at Dacre, Ontario, Canada, which has been worked for the past year and a half and which is controlled by Willam J. Spain, 417 Fifth Avenue, New York, a concentrating plant is now being installed and is expected to be in running order by January, 1916. The ore is a very high-grade molybdenum sulphide. The great interest which is being taken at present in molybdenum is due to the fact that molybdenum has properties very similar to tungsten and can be used as a substitute for tungsten in various applications, especially in special steel manufacture. This is of considerable importance in view of the present high price of tungsten.

The Relation of Chemistry and Mechanical Manipulation to the Evolution of the Glass Industry*

BY ROBERT L. FRINK

To do more than touch upon the generalities of the subject, would evolve a great amount of data, and lengthy explanations. It would necessitate to present for criticism or ridicule many of the mooted questions which many now consider as fixed and well determined from a practical standpoint, while from a chemical standpoint they must be considered irrational. Therefore I must and will endeavor to deal with those generalities only which show the progress of the glass industry from a mechanical and chemical standpoint, and I will touch only upon those specific conditions and materials that go to make up success or failure in handling, forming and making of glass articles by the processes of to-day.

If one has access to the information which is upon record in the Patent Office or in memoirs or can be obtained from personal conversation with some of the older men in the industry, it is astounding to learn that many of our advanced mechanical appliances and means for manipulating glass, were conceived, and in some instances exploited, fifty, sixty or more years ago There is perhaps no instance in the annals of the Patent Office wherein the understanding of the true properties and requirements of glass are set forth in any more definite manner than in the old French patent of Loup, of 1854, wherein Loup has conceived and designed a mechanical device for the producing of cylinders of glass by means of what is at present known as a "bait member." This is lowered into a body of molten glass, withdrawn therefrom, air pressure is supplied within the cylinder thus formed, and then a cylinder is progressively drawn from the molten body. However, Loup recites that the temperature, the specific heat, the expansion and contraction of the glass, and the air within the cylinder are all factors in producing a uniform cylinder of glass, and that composition affects all these factors.

Later Opperman attempted to produce the same result by a considerably different process, using purely mechanical devices throughout to obtain the drawing of the cylinder, the introduction of the air thereto, and the control of the pressure of the air therein. He, however, makes no specific reference to any of the physical properties of the glass, or their effect upon the success or failure of his apparatus to produce the required result.

Later Sievert, Lubbers, George and Shortle, and others, besides myself, attempted the production of glass in this manner, and at a still later date the American Window Glass Company in 1904 took up Lubbers' conception, a somewhat crude but nevertheless demonstrative device, and exploited same, introducing at Alexandria, Indiana, a full equipment for the production of window glass. This process comprised the lowering into a bath of glass a pipe similar to the ordinary glassblower's pipe, although larger and heavier, withdrawing this pipe from the bath of glass, introducing the air through the pipe member, and controlling the air pressure in a manner as to blow out and form a cylinder of glass.

The preliminary results obtained in this operation appeared to be perfect, so far as the forming of the cylinder was concerned, and the officers of this company had so much confidence in the results that they installed these machines in a number of their plants. Certain modifications and improvements were added whereby it was deemed that the cost of manufacture, maintenance and upkeep would be reduced below that of the original plant. It was found, however, that under practical operating conditions there were other fatcors, hidden ones, which greatly affected the amount of glass which could be delivered to the warehouse, and that it was quite a different proposition to make cylinders of glass in quantities, sizes and thickness, and cut them into lengths, flatten them, and again cut them into sheets the quality and perfectness of which would permit of their being placed upon the market. A cylinder might be made that was perfect and drawn perhaps to a length of 20 ft. or more, but when it was attempted to lower this cylinder, cut it up into lengths or flatten it into flat panes of glass, breakage would occur, and this breakage sometimes would be in excess of 80 per cent of the total production. At times it amounted to as much as 90 per cent of the possible production.

The cause of this breakage seemed entirely obscure to the most practical and successful glassworkers and glassmakers, and for a time it seemed as though the prediction of old glassworkers was about to prove true, namely that "the devil resides in glass and man can not take him out." However, as is usually the case when the practical "rule-of-thumb" man meets unknown difficulties, he turns to science for assistance, and by the combination of logical theory with methodical practice the problem is solved.

It was found that these breakages occurred as a result of the differences which existed in the composition of the glass comprising an individual cylinder, and that the operators were seriously hampered by the lack of information concerning the correct temperatures to be used, concerning the difference of expansion and contraction between the metal forming the bait and the glass, concerning the effect of the chemical composition of the glass and the chemical reactions caused by the conditions of operation of the furnaces, namely, temperature, fire conditions, quantity of material melted or moved through the furnace, and the action of combustion gases.

After lengthy investigations had been conducted and these conditions had been determined, and the chemical and physical properties of glass had also been investigated, many of the early difficulties were overcome, and the process of mechanically forming glass cylinders became clear and much simplified, and to-day stands as one of the foremost successful inventions of the age, although this very same process and the principles involved therein were conceived and attempted by Loup in 1854. Loup might have been successful in accomplishing what is accomplished to-day had he been in a position to command the results of research and the benefit of the progress which has been attained in our present-day chemical industries, and had he been able to get the financial assistance, whereby he could have worked out the conceptions set forth in the preamble of his patent application. For therein he hinted at or directly stated the primary factors which govern the sequence and method of producing glass cylinders. All attempts prior to 1904 unquestionably failed because of the lack of knowledge of the material that the experimenters were working with, its mechanical constitution and means of controlling such constitution.

In 1882 Clark, and subsequently Schulze-Berge, Sievert, Dolan, George and Shortle, Fourcault, Colburn and I attempted making glass in sheet form by withdrawing a sheet of glass from a bath of molten glass, or by flowing a stream of metal in sheet form over a weir or dam-like aperture, or by forcing it through an aperture. Even Mr. Edison has attempted the production of sheet glass in this form, and to this day it is

*An address made before the First National Exposition of Chemical Industries in New York City on Sept. 25, 1915.

still being attempted. Vast sums of money have been expended in an endeavor to produce a sheet of glass uniform in thickness and having plane surfaces, but all attempts so far have been commercial failures, and I firmly believe for no other cause than our lack of knowledge concerning chemical and physical control of those factors which co-operate to produce a homogeneous glass.

In 1903 I produced sheets of glass from 0.003 in. to ⅜ in. in thickness, which appeared to be perfect when entering the annealing oven and coming from the forming device, or before they had cooled to a temperature of less than 250 deg. C. But below this temperature they would begin to warp and get distorted in a manner which made them entirely unfit for commercial use. It has been said that there is one sheet machine on which there has been over a million dollars expended in an endeavor to produce a sheet of glass directly from the bath of molten glass, but failure has as yet been the only result, due entirely to "warping" as it is called, and to lack of homogeneity.

Other factors which have been a great bane to the sheet glass manufacturers are the mottled appearance of the glass and the difficulty in producing glass which can be placed into windows and retain its surface lustre or be free from "fading" as it is termed. This fading is in fact a disintegration or delinquence of the surface due to adsorption or the chemical effects of gases or moisture coming in contact with the surface of the glass and combining with the constituents thereof.

In the making of pressed ware, i. e., tumblers, jelly dishes, cake dishes, punch bowls, etc., much difficulty is experienced in obtaining a glass which can be manipulated in sufficient quantities in an iron mold and pressed out in the desired form, so as to obtain the tone configuration of the mold without showing imperfections. In recent years, since the advent of the pressing and blowing machines for the making of bottles, milk jars, table ware, fruit jars, etc., many of the difficulties before mentioned have presented themselves. That is to say, the machine may be of good design and produce ware of commercially perfect shape from the molds, but in subsequent operations to which this ware is subjected, many sources of loss occur. In the making of goblets, shades, etc., after the article has been formed from the molten mass, and either cooled to atmospheric temperature or reduced in temperature to 100 or more degrees below the solidifying point, it must be again subjected to the impinging heat of a flame to round the edges or permit a reshaping of the piece, and this treatment will often cause the ware to fly to pieces. Or perhaps the ware may be subjected to a grinding operation, and the abrasive effect of the wheel or stone or perhaps the rise of temperature occasioned by the grinding will produce breakage. In the case of milk jars, fruit jars, or bottles subjected to sterilizing or pasteurizing operations, the sudden heating or cooling of the same would cause them to break and possibly incur the loss of the liquid placed in them, and all of these conditions are due to heterogeneity.

Perhaps one of the greatest banes of the electric lamp manufacturer is the breakage of his stems, or the joints between the stem and the bulb, or possibly the imperfect sealing of the leading-in wires. Again another defect which he has to contend with and which is due to lack of chemical control, is the smutting of the bulbs, this being again a chemical effect upon the surface of the glass caused by the contact of gases which attack the glass and reduce the lead therein.

I have gone to some length in enumerating some of the principal causes of loss in production and lack of satisfaction as to quality in the different cruder and grosser branches of the glass industry, in which it has been thought inadvisable, or at least unprofitable, to employ a scientist or chemist for the purpose of investigating and determining the causes of these losses. This is due, to a great extent, to the fact that the glass manufacturers and the men in control of the glass factories are, in the majority of cases, men who have grown up in the business and have been compelled to devote their time to the practical problems as they saw them and had no time to investigate the possibilities of scientific research.

As a matter of fact, there are a great many so-called first-class glassmakers, and men who are responsible for large productions and finest quality of ware, whose knowledge of the constitution of glass begins and ends the moment when the material enters the furnace, and as a matter of fact many of them still believe that glass is composed of sand which has been reduced to a molten state by being placed in a mixture with such ingredients as lime, soda, potash, feldspar, fluorspar, cryolite, antimony, zinc oxide, borax, or whatever else their batch formula may call for, and that after it has been subjected to fire all of the ingredients with the exception of sand go up the stack. It is only the more progressive individuals who have studied this matter, who have benefited by research, and who have any true conception of the actual composition of the glasses that they are making. However, even they, in many instances, have no true knowledge as to the properties given to the glass by the materials they use, and in fact there is but little actual specific knowledge available.

It is true that in Europe, and in recent years also in this country, there has been considerable progress in the making of certain glasses for special purposes, and we owe much to Guignand, Bontemps, Schott, Hovestadt, Harcourt, and others, who having contributed greatly to our knowledge of the composition and making of optical glasses manufactured in closed pots, or under conditions whereby perfect control could be had of the atmospheric, melting and temperature conditions. But there has been little or nothing done, in a practical way at least, to give us specific information as to the effects of the chemical constituents of glass when the same is made in tank furnaces, in open pots, or under varying fire conditions or how they affect our various processes of manufacture. As I have found by extensive experiments and research, the tensile, crushing and electrical strength, also the fluidity or viscosity of glass can be varied through a wide range by variation of these conditions.

Further, it seems to be pretty well established that in the making of glasses in tank furnaces, the homogeneity of the glass is governed to a considerable extent by the uniformity of fire conditions. However, I make bold to state that the chemical constitution of a glass is the more important factor which makes possible the production of a homogeneous glass in a tank furnace. I mean that the relative proportions of the constituents are more important than the actual constituents; that is to say, a glass may be composed of soda, lime and silica only, and unless the proper chemical proportions are maintained we will not get a uniform and homogeneous product under variable fire conditions, while on the other hand other combinations can be used and if the proportions are right, and the fire conditions are properly maintained for such proportions, homogeneity will result. In this, I believe, we have before us one of the most salient problems that affects the greatest number of glass manufacturers.

It is true that for the production of certain classes of articles, like thermometers, measuring vessels, etc., it is necessary to observe uniform and definite composition, in order that the required expansions, heat re-

sisting properties, electrical properties, etc., may be obtained. But for the glass manufacturers who are producing the greatest tonnage, and the greatest amount of ware in dollars and cents throughout the country to-day, the vital problem consists of:

What can I do to obtain the greatest amount of melted material for the minimum cost? How can I produce it in finished product for the minimum cost? What will assist me in putting my ware into packages, ready for the market, with minimum breakage or loss?

Right here is where the chemical industry can be of incalculable assistance to the glass industry, for if the manufacturers and operators of our chemical works, who mine, manufacture or sell the raw materials to the glass manufacturers will but put their shoulders to the wheel they will assist in turning the glass manufacturer's prejudiced mind from his pagan thought that —"an ounce of practice is worth a ton of theory," and they will, in a short time, sell to the glass manufacturers much of their by-products, waste material, or perhaps raw material, at a larger profit to themselves and at the same time enhance the profit of the glass manufacturer.

I regret that I am not in a position to elucidate more clearly this subject; I can, however, point out a few instances to show the possibilities.

In the average glass factory when trouble occurs and the glass contains various imperfections, or when breakage begins to become excessive, the first thing that will be investigated will be the sand pile. The sand will be immediately condemned should it be a little dark in color or a little too fine or a little too coarse, or not exactly of the same shade of color as the sample (which, in many factories, can be found preserved for the purpose of comparison, and which perhaps was selected at a time when some abnormally good runs were made). The next step will probably be to change the sand and get a carload or so from some other source of supply, when in reality sands do not differ by more than 1 or 2 per cent in the amount of silica which they contain.

Now if instead the manufacturer had gone to his lime bin, and had taken a sample of the lime when his trouble started and had it analyzed it is probable that he would have found that the actual calcium oxide content had increased or diminished by 10 or 15 per cent above or below normal. It is possible that he had been using before a lime which carried 80 to 82 per cent of CaO, but on the next order the manufacturers may have been short of his particular kind and may have shipped him a car from some other source or from another one of their mines where the material had been taken from a greater or lesser depth in a stratum of rock, and which may have contained, say, 50 to 60 per cent of CaO and from 20 to 30 per cent of magnesium oxide. Now his melting conditions had been adjusted originally for lime which contained approximately 80 per cent of CaO with only 2 per cent, or at the most 3 per cent of MgO, so that they were not adjusted to the use of the new lime, with the result that the product was "cordy," "stringy" or hard glass.

In another instance the glass worked may have been using an oxide of manganese for decolorizing purposes which contained, say, approximately 80 per cent of MnO_2, but for some reason he may have purchased manganese from another source and the material may vary 5 to 15 per cent in MnO_2. The result is that the color of his glass goes from white to pink or green, and his glassmaker begins to use various "dopes" for the correction of such troubles, without any knowledge whatsoever of the effect produced by what he uses other than that it is "blue" or smalts, arsenic, antimony, borax, cryolite, fluorspar or nitre. Now if the manufacturers of these products would join with the glass manufacturer in investigating these troubles or would furnish material of known composition, the glassmaker would soon learn to appreciate the value of such knowledge.

There are innumerable instances of this kind. If some of our manufacturers would take steps to furnish to the glass manufacturer raw materials of exact composition which would give him a more uniform product with less melting cost and less loss, or if they would, as outlined above, lend some encouragement to the founding of establishments for investigating problems of glassmaking a great deal could be accomplished.

Lancaster, Ohio.

Inflammability of Mixtures of Gasoline Vapor and Air

The Inflammability of Mixtures of Gasoline Vapor and Air is discussed by G. A. Burrell and H. T. Boyd in Technical Paper 115, of the Bureau of Mines.

The authors in their conclusions say in part: "Two methods for determining the content of gasoline vapor in air are discussed. One has to do with the introduction of the mixture into an exhausted glass vessel, cooling it at the temperature of liquid air, removal of the air, and finally the measurement of the partial pressure of the gasoline vapor by means of a manometer attached to the liquefaction bulb.

"Another method consists in burning the gasoline vapor in oxygen and, from the contraction and carbon dioxide produced, calculating the percentage of gasoline vapor.

"When a 100-c.c. Hempel explosion pipette was used and the mixtures were ignited from the top, there was obtained as the lower limit of complete inflammation a value lying between 1.9 and 2.0 per cent of gasoline vapor. The upper limit under these conditions was found to be between 5.2 and 5.3 per cent of gasoline vapor. The gasoline used had a specific gravity of 73 deg. B. Under the same conditions, except that the mixtures were ignited from the bottom, there was obtained a value lying between 1.5 and 1.6 per cent of gasoline vapor as the low limit. With the same grade of gasoline, with a 2800-c.c. vessel, and with ignition from the bottom by means of an electric flash produced by pulling apart two wires through which a current of 7 amp. at 220 volts was flowing, there was obtained a value lying between 1.4 and 1.5 per cent of gasoline vapor. The high limit under these conditions lay between 6.0 and 6.4 per cent of gasoline vapor.

"When the initial temperature is increased before igniton of the mixtures the low limit is gradually decreased until with an initial temperature of 400 deg. C. the low limit lies between 1.02 and 1.22 per cent of gasoline vapor.

"The range of complete combustion for mixtures of gasoline vapor and air is very narrow, and is between about 1.5 and 2.5 per cent. The amount of carbon dioxide produced reaches a maximum at 2.5 per cent of gasoline vapor. At this point, as the percentage of gasoline vapor increases, carbon monoxide begins to form. At 4.1 per cent of gasoline vapor there is produced 14.0 per cent of carbon monoxide."

The **Bausch & Lomb Optical Co.** received four Grand Prix, one medal of Honor and one Gold Medal at the Panama-Pacific Exposition for the excellence of their products. The four classes in which Grand Prix were received were optical instruments, balopticons, engineering instruments, and range finders. The Medal of Honor was awarded the photomicrographic apparatus and the Gold Medal was awarded the Zeiss lenses.

The Electrolytic Precipitation of Gold, Silver and Copper from Cyanide Solutions*

BY G. H. CLEVENGER

The present unsettled condition of the metal market, more particularly as regards zinc, which is used now almost exclusively as a precipitant in the cyanide process, makes a consideration of electrolytic precipitation, which is apparently the most feasible substitute, of particular interest at this time.

The electrolytic precipitation of gold, silver and copper from cyanide solutions in connection with the cyanide process of gold and silver extraction, has frequently been the subject of satisfactory laboratory experiment, but much less frequently of successful commercial application. This comes about through the fact that experiments carried on for a few hours in the laboratory give no true indication of the life of anodes, formation of by-products, etc., to be expected in continuous operation.

My purpose in presenting the present paper is not to give a theoretical discussion of the subject or to make new proposals for improved types of electrolytic precipitation apparatus, but rather to describe the few commercially successful installations which have been made, calling particular attention to the difficulties which have arisen in their operation, in the hope that it may prove useful to those who have to do with the installation of electrolytic precipitation equipment.

In order that those of our members who are not familiar with the cyanide process may properly appreciate the peculiar and difficult problem which the complete precipitation of gold and silver from dilute cyanide solutions presents, I will digress sufficiently to make this clear before taking up the description of the various attempts to solve the problem. The solutions which are precipitated in present-day cyanide practice may contain a great variety of compounds arising from the decomposition of the cyanide, as well as from its combination with elements occurring in the ore treated, or introduced by chemical methods of precipitation. The principal constituents of such solutions, if zinc precipitation were not used, would be: Simple alkaline cyanides, alkaline hydrate, gold and silver, and copper if it occurs in a soluble form in the ore undergoing treatment. The proportion of these various constituents present, particularly of the gold and silver, is extremely small compared with the amounts of metal present in solutions made by extraction processes in other industries.

In general the simple alkaline cyanide, as indicated by the Liebig titration test, will range in present-day practice from a trace to 0.25 per cent, or a maximum of 1/400 of the solution. In certain cases of sand treatment of silver ores stronger solutions are used, but in general the cyanide strength of the solutions precipitated will fall well below the upper limit given. The alkali generally added is lime, although caustic soda has been used. There is rarely over 100 points present and most generally much less than this, and in some cases practically no protective alkalinity. (One hundred points of alkali correspond to a saturated solution of lime in distilled water at 20 deg. C., i.e., 0.13 per cent.) The proportion of alkali present is therefore in many cases less than the cyanide.

The gold present will range from nothing to 0.5 ounce (15 grams) per ton, and the silver from a trace to 10.0 ounces (292 grams) per ton. In general the proportion of gold and silver in solution is much less than the upper limits given.

*A paper presented at the 28th general meeting of the American Electrochemical Society, in San Francisco, Sept. 16 to 18, 1915.

The grade of the ore treated does not always form a safe criterion of the gold and silver content of the solution, for the reason that the ratio of the weight of solution used to the weight of ore treated, or, as it is generally termed, "the dilution," varies greatly, but in general, as might be expected, is greater with high-grade ores. Thus, if three tons of solution are used in treating one ton of ore, we have a 3 to 1 dilution, and the recoverable value of the ore has been transferred to three parts of solution, the average value of which would be one-third of the recoverable value of the ore treated; or, to take the concrete case of an ore assaying 0.50 oz. (15 g.) of gold per ton (approximately $10 per ton) from which 90 per cent of the gold can be extracted by cyanide solution, there would be dissolved by the solution 0.45 oz. (13.2 g.) ($9) per ton of ore treated. With a 1 to 1 dilution the average content of the solution per ton would be 0.45 oz. (13.2 g.) ($9); with a 3 to 1 dilution the average content of the solution per ton would be 0.15 oz. (4.4 g.) ($3); with a 5 to 1 dilution the average content of the solution per ton would be 0.09 oz. (2.6 g.) ($1.80).

It will, therefore, be apparent that this stage of the cyanide process, the transference of the gold and silver from the solid state as occurring in the ore, to the liquid state as dissolved in the cyanide solution, is unlike most other steps in metallurgy, which are in general to successively concentrate the metal sought into a smaller weight of material. Exceedingly small as is the proportion of gold and silver present in ores which it is possible in present-day practice to profitably treat by cyanidation, the proportion of gold and silver in the solutions requiring precipitation are generally still smaller.

Perhaps a clearer idea of the small amount of metal involved, particularly in the case of gold, will be obtained by expressing the proportion fractionally. In solutions containing 0.50 oz. (14.6 g.) of gold per ton (approximately $10), an unusually high proportion, the gold would form only 14.6/1,000,000 or 1/58,332 part of the solution. In the case of waste solutions, which are or should be precipitated before they are discarded, it is not unusual to deal with solutions containing less than 0.01 oz. (0.29 g.) of gold per ton (20 cents), or only 1/2,916,600 of the total weight of the solution. Tail solutions containing only 1 or 2 cents values per ton are regular practice at many mills using zinc dust precipitation.

At the present market price of silver (about 50 cents per ounce) there would be required about forty times the weight of gold present to give an equivalent value in silver. Therefore, in the treatment of silver ores a much greater weight of metal would be involved, but still the relative proportion of metal to the total weight of solution is small. As gold and silver most frequently occur associated, the absolute weight of metal to be precipitated will depend upon the ratio of these two metals in the ore treated. The greater weight of metal involved in the treatment of silver ores or ores in which silver predominates, perhaps in a certain measure explains the greater ease with which solutions resulting from the treatment of such ores are handled by all precipitation processes.

Copper in solution is an incident of gold and silver extraction, as at present there is no effort made to recover copper in this way; however, this is an interesting possibility, and would be feasible provided the cyanide combined with the copper could be economically regenerated. In many cases the proportion of copper in solution will be less than that of the gold and silver, and, so far, even with electrolytic precipitation, there has been no serious attempt to treat gold and silver

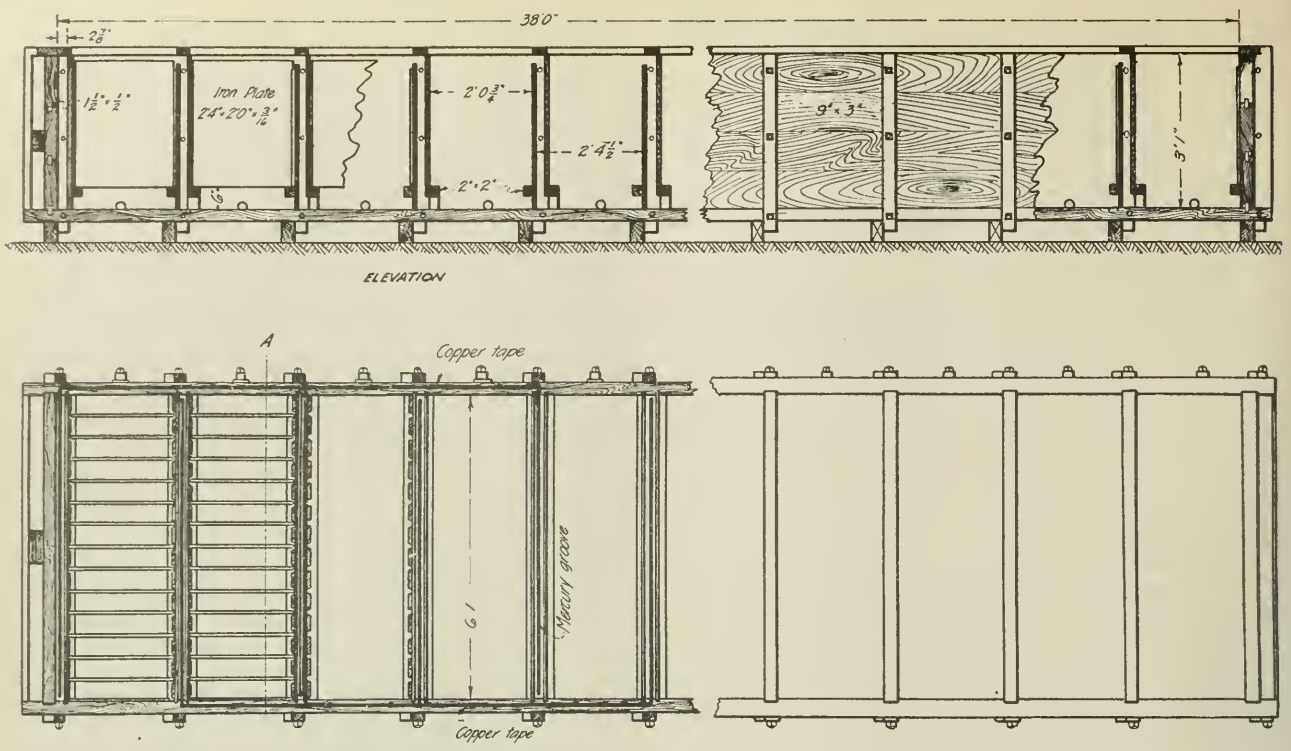


FIG. 1—CONSTRUCTION OF BOXES FOR SIEMENS-HALSKE PROCESS

ores by the cyanide process unless the proportion of readily soluble copper was considerably below 1.0 per cent. The interference of copper with other methods of precipitation, as well as its prejudical effect upon extraction, make a consideration of its behavior with electrolytic precipitation of particular interest, but beyond the province of the present paper.

The electrolytic precipitation of gold and silver from cyanide solutions, therefore, involves the practically total precipitation of an extremely small weight of metal from solutions containing a comparatively small proportion of soluble salts, and which are therefore poor electrical conductors. The fact that the alkaline cyanides are readily decomposed by electrolysis and that the economy of the cyanide process depends upon the continued re-use of the solvent make it imperative to precipitate with the minimum decomposition of cyanide, and preferably with a regeneration of cyanide. The difficulty of the problem at best will therefore be apparent.

Siemens-Halske Process, on the Rand, South Africa

The precipitation of gold and silver from cyanide solutions by electrolysis, employing a soluble anode of the metal to be deposited, had been practiced in electroplating long before the complete precipitation of gold and silver from the dilute solutions resulting from ore treatment was attempted by electrolysis, using an insoluble anode.

In 1887 a British patent was granted on the MacArthur-Forrest process of gold and silver extraction, involving the use of dilute solutions of potassium cyanide and zinc precipitation. In the same year, Dr. Siemens, working independently and acting upon observations made at his plating plant at Berlin, Germany, taken together with the statements of chemical authorities that gold was soluble in solutions of the alkaline cyanides, developed a process of gold and silver extraction involving the use of dilute solutions, more dilute than those at first used with the MacArthur-Forrest process, and electrolytic precipitation.

In the course of this work zinc filings had been tried as a precipitant, but with the very dilute solutions employed electrolytic precipitation proved more satisfactory. The first experimental plant was erected at Siebenburgen for extracting gold from concentrates, and although the process was in successful operation as early as 1888 in other mining localities it was not until a number of years later, in 1893, that the Siemens-Halske process was introduced into the Rand gold field of South Africa.

On the Rand, at first, only the sand portion of the ore pulp resulting from the stamp-crushing and plate-amalgamation process could be successfully treated by cyanidation, as leaching was the only method of treatment then in use. The solutions resulting from sand treatment contained sufficient free cyanide to give satisfactory results by ordinary zinc-shaving precipitation, as then practiced. This method of precipitation was, therefore, almost universally used for these solutions.

With the advent of the decantation method of treatment for the unleachable portion of the pulp, which had previously been allowed to accumulate on account of not being amenable to treatment by leaching, the problem at once arose of precipitating from large volumes of solution which were weak in both cyanide and gold on account of the high dilution necessary in treating slime by the decantation method.

At this time the ordinary zinc-shaving method of precipitation did not give satisfactory results when used with very weak solutions. The Siemens-Halske electrolytic process of precipitation, therefore, came into very general use for precipitating the solutions resulting from slime treatment.

The Siemens-Halske process was first introduced at the Worcester mine. Installations at other mines rapidly followed until at one time there were about twenty in operation on the Rand. In the Siemens-Halske process, iron anodes ⅛ to ¼ in. (0.3 to 0.6 cm.) thick, and lead-foil cathodes about 0.00032 in. (0.008 cm.) thick were used. In general, the anodes and cathodes were set vertically and about 1½ in. (4 cm.) apart. There was considerable variation in the size

and arrangement of the anodes and cathodes. At the Worcester plant they were 7 ft. long by 3 ft. wide (2.1 x 0.9 m.), but in later installations, to facilitate handling, they were made smaller, as shown in Fig. 1. The anodes were enclosed in sacks of textile material for the twofold purpose of preventing short circuits and of collecting the prussian blue and iron oxide formed from the iron anodes.

The lead-foil cathodes were frequently cut in narrow strips for the purpose of increasing the surface. These were strung upon iron wires mounted in light wooden frames. Another expedient which gave still greater surface was to cut the lead into shavings similar to zinc shavings. These were packed into the space between the covered anodes.

Various arrangements of the precipitation units were tried, but the one which seemed to be the most favored was to construct the containing box as shown in Fig. 1 and Fig. 1a, with alternate wide and narrow compartments, the narrow compartments serving for the downflow of the solution, while the anodes and cathodes were suspended in the wide compartments, through which the solution had an upward flow. This general arrangement will be recognized as being similar to that of the boxes used for zinc-shaving precipitation.

The current density used was from 0.03 to 0.06 amp. per square foot (0.33-0.66 amp, per sq. m.) of anode surface. The aim was to obtain a coherent plating of the gold upon the lead cathodes. After sufficient gold had accumulated upon the cathodes (2 to 12 per cent of their weight) they were removed, melted and the gold recovered by cupellation, either locally or at a central reduction plant.

There was a long and bitter controversy on the Rand regarding the relative merits of zinc and electrolytic precipitation. In 1898, Betty, by means of a drip of strong cyanide solution at the head of the zinc boxes, in conjunction with the zinc-lead couple, which was first proposed by MacArthur in 1894, demonstrated that zinc precipitation could be satisfactorily used for solutions low in both cyanide and gold. After satisfactory precipitation of these dilute solutions by zinc became possible, electrolytic precipitation rapidly lost ground and finally was entirely superseded by zinc precipitation.

Practice at Minas Prietas, Mexico

E. Andreoli, early in 1895, while working with the Siemens-Halske process in South Africa, accidentally discovered the lead peroxide anode, and although the advantages of peroxidized lead over iron as an anode material were at once recognized, it does not appear to have been used to any exent in that locality, possibly for the reason that electrolytic precipitation, at the time that this development was announced, was being rapidly displaced by zinc precipitation. After investigating many possible cathode materials, Andreoli sugested iron as being the best on account of its cheapness, strength, and the firm adherence of the gold to it. Borchers, however, states that from the electrochemical standpoint the use of iron cathodes is theoretically incorrect. Andreoli proposed recovering the gold from the iron cathodes by dipping them in a bath of molten lead. The gold was to be recovered from the lead by cupellation. The iron cathode used in this way does not appear to present any advantage over the lead-foil cathode, as it also involved the use of lead and necessitated the operation of cupellation.

In 1899, Charles Butters, who had been prominently identified with the introduction of the Siemens-Halske process in South Africa, assisted by two members of his former staff, H. T. Durant and E. M. Hamilton, developed a new electrolytic precipitation process which

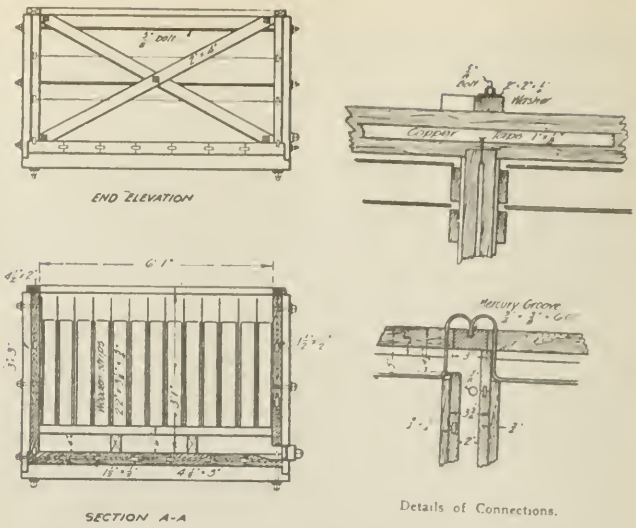


FIG. 1A—DETAILS OF SIEMENS-HALSKE BOXES

was first sucessfully used for a number of years in connection with the cyanidation of a large deposit of pan-amalgamation tailings, and later of ore directly, from the mine at Minas Prietas, Mexico.

The original installation for electrolytic precipitation consisted of six wooden boxes, as shown in Fig. 2, 30 ft. (9 m.) long by 10 ft. (3 m.) wide and 5 ft. (1.5 m.) deep, having a slope of 1 in. to the foot (8 cm. to 1 m.) toward one side, to facilitate the removal of precipitate. The boxes were divided by wooden partitions into alternate wide and narrow compartments, twelve of each. The partitions were so arranged as regards the bottom that the narrow compartments throughout the box served only for the downflow of the solution, whilst the wide compartments, in which were suspended the anodes and cathodes, served for the upward flow of solution.

This general arrangement of the compartments is the same as that used with the Siemens-Halske process. Each wide compartment was fitted with eighteen lead anodes whose surface was coated with lead peroxide, formed by electrolysis in a special cell, and seventeen cathodes composed of lead foil, cut in strips, strung upon wires supported by wooden frames similar to the cathodes used with the Siemens-Halske process in South Africa.

The current was supplied by two Siemens-Halske dynamos, each capable of developing 250 amp. at 30 volts, feeding into copper bus bars 1¼ x ¼ in. (3.1 x 0.6 cm.) laid on top of the boxes.

In order to insure good contacts, the wires leading from the individual anodes and cathodes were soldered to the bus bars, mercury-cup contacts having proved unsatisfactory.

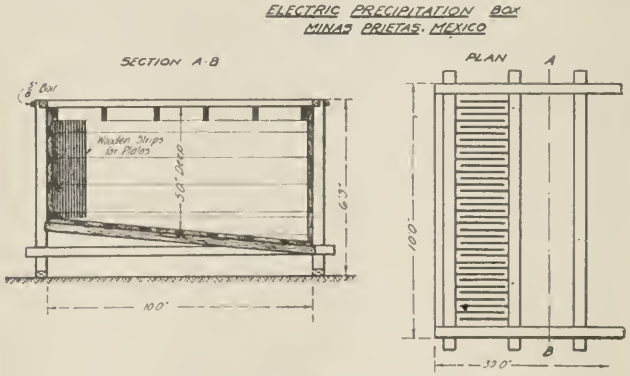


FIG. 2—PRACTICE AT MINAS PRIETAS, MEXICO

The solution passed through three sets of boxes, each set comprising two boxes set in tandem. One set of two boxes was used for precipitating the solution resulting from sand treatment and two sets of four boxes for precipitating the solution resulting from slime treatment.

The current density was so regulated that the metals were deposited as a flocculent precipitate which largely fell to the bottom of the compartments in the form of a fine slime, as in zinc-shaving precipitation, rather than as an adherent coating upon the cathodes as in the Siemens-Halske process.

After a short period of operation, it was found that the precipitate did not all fall to the bottom of the box, but that part of it formed as a rather loosely-adherent mass on the cathodes. This necessitated washing and shaking of the cathodes when it was desired to make a complete clean-up. It was soon apparent that the fragile lead-foil cathodes could not long withstand such treatment, so an investigation was started with the view of finding a more satisfactory cathode. This resulted in abandoning the lead-foil cathode in favor of a cathode made from ordinary tin-plate, which possessed the necessary strength and from which the precipitate could be readily brushed without removal of the cathodes from the containing box.

The pan-amalgamation tailing cyanided at this plant resulted from the treatment by raw pan-amalgamation of a comparatively simple siliceous silver-gold ore. The tailing contained copper, mercury and chlorides as a result of the chemicals added during amalgamation. After the tailing deposit had been exhausted, the low-grade ore which had been left in the mine was treated. The pulp was separated into sand and slime, the sand being treated by percolation and the slime by agitation, natural settlement and decantation. The volume of the solution precipitated varied as did also its metal content. The percentage of cyanide and alkali were less variable, but by no means constant.

Below are given average figures covering two months' operation, for solutions resulting from sand treatment when pan-amalgamation tailing was being treated. Average amount of solution precipitated per 24 hr., 216 tons. Current density 0.55 amp. per square foot (60 per sq. m.) of anode surface. The voltage across the anodes and cathodes varied in the different compartments, but averaged about 3. The head solution, or solution entering the precipitation boxes, contained: 0.147 oz. (4.14 g.) gold per ton; 3.51 oz. (102.4 g.) silver per ton, and 0.0792 per cent of cyanide in terms of potassium cyanide. The tail solution or solution leaving the electrolytic precipitation boxes contained 0.013 oz. (0.379 g.) gold per ton; 0.29 oz. (8.46 g.) silver per ton, and 0.0938 per cent cyanide. The gain in cyanide was 0.0146 per cent. As there was used 1.2 tons of solution in treating each ton of sand, the cyanide apparently regenerated amounted to 0.35 lb. (0.16 kg.) per ton of sand. The percentage of gold precipitated was 91.0 and the percentage of silver precipitated was 91.7. No attempt was made to lower the gold and silver in the tail solution, as none of it was used for final washes.

The following are average figures covering the same two-month period for the precipitation of solution resulting from slime treatment: Average amount of solution precipitated per 24 hr., 480 tons. Current density 0.3 amp. per square foot (3.3 per sq. m.) of anode surface. The voltage across the anodes and cathodes averaged 2.6. The head solution contained: 0.133 oz. (3.88 g.) gold per ton; 1.45 oz. (42.3 g.) silver per ton, and 0.0409 per cent cyanide. The tail solution contained: 0.055 oz. (0.160 g.) gold per ton; 0.15 oz. (4.37 g.) silver per ton, and 0.0527 per cent cyanide. The gain in cyanide was 0.0118 per cent. As there was used four tons of solution in treating each ton of slime, the cyanide apparently regenerated amounted to 0.94 lb. (0.43 kg.) per ton of slime. The percentage of gold precipitated was 88 and the percentage of silver 89.6. When the solution flow was cut down to two-thirds normal, the tails contained 0.0025 oz. (0.073 g.) gold and 0.06 oz. (1.75 g.) silver per ton. The regeneration of cyanide was doubtless greater with the solution resulting from the treatment of the slime on account of the greater percentage of copper which it contained. When treating ore directly from the mine, which contained little or no copper, the regeneration was not sufficient to be detected by ordinary titrations.

(To be concluded)

Paint*

BY G. B. HECKEL

Paint is a product of science and civilization, and a result of progress and evolution.

History of the use of paint by all races is practically the same. The first pigments used are the natural earth colors or simple vegetable dyes. They are devoted to personal decoration—commonly heraldic—and later their use is extended to other decorative purposes. It is only in a higher stage of development and civilization that the protective value of paint is recognized. This evolution is the natural accompaniment of change from the nomadic state, where dwellings are temporary, to the fixed life of civilized society.

Let us consider a typical high-grade paint formula. It contains the following ingredients:

Analysis of Pea Green
(United States Standard Measure)

	Per cent
Pigment by weight	48.00
Thinner by weight	52.00
	100.00
Thinner is composed of:	
Linseed oil	85.00
Asphaltum spirits	3.00
Turpentine	1.00
China wood oil	2.00
Japan dryer	9.00
	100.00
Composition of pigment:	
Basic carbonate white lead	15.00
Basic sulphate white lead	20.00
Zinc oxide	44.00
Magnesium silicate (asbestine)	3.00
Calcium carbonate	2.00
Barium sulphate (blanc fixe)	10.00
Aluminium silicate	3.00
Lead chromate	2.30
Ferric-ferro cyanide	.70
	100.00
Coloring is composed of:	
Pure chrome green	100.00
Composition of Japan dryer:	
Kauri gum	1.67
Oxide lead	8.45
Manganese peroxide (black oxide of manganese)	2.00
Linseed oil	26.44
Turpentine	61.44
	100.00

Besides these ingredients that are mentioned on the label, we may also notice that the container is made of tin plate; that the can is soldered; that the labels are printed with two colors of printing ink on white paper, and pasted on the can. Finally we may recall that such cans are packed with sawdust in wooden boxes nailed together with steel wire nails. Keeping in view the finished can and its contents, I think you will catch my drift when I say that all science and all civilization have contributed to the making of the can of paint bearing this label and that without science and civilization it would be unthinkable.

*An address made before the First National Exposition of Chemical Industries.

Components of Thinner

Let us consider briefly the ingredients, one by one: The first is **linseed oil**, a product of the flax plant *Linum usitatissimum*. The flax plant was not first cultivated by man for the seed or its oil. Its earliest use was for the making of linen cloth. The great masters of early European art knew nothing of linseed oil, and the first use of the seed was medicinal. To-day in the United States alone over 25,000,000 bushels of flaxseed are consumed annually in the manufacture of linseed oil, the great bulk of which goes to the production of paint and varnish. To produce so much seed requires from 2,000,000 to 2,500,000 acres of soil. Its cultivation requires many farmers and laborers, much special machinery; its storage and transportation utilizes elevators, railroads, steamships; its use for oil-making requires elaborate plants, much special machinery, and the treatment of the oil for its various uses involves chemistry and the mechanical arts. Moreover, the oil-growing flax is itself a product of agricultural science, a science which is to-day more ardently pursued by plant specialists than ever before. The proper preparation and use of linseed oil involves the results of profound study and investigation, which to-day are still far from completion.

In the manufacture of linseed oil the flaxseed, cleaned from foreign seed and other impurities, is first ground in a series of roller mills. The resultant meal is treated in a special heater with live steam to break up the oil cells. This hot meal is then pressed into the desired form and size for the oil presses, in a cake former, and a number of those cakes are stacked, one above the other, in camel's-hair or other fabric cloths, between the plates of a specially devised hydraulic press. An enormous pressure is applied and the expressed oil is filtered and collected in settling tanks where the moisture, plant mucilage, etc., settle to the bottom, while the clear oil collects on top and is drawn off and sold as raw linseed oil.

Linseed oil is a very complex organic chemical compound, but consists essentially of the glycerides of a number of fatty acids. Of these the most important in connection with our subject are the glycerides of linolic and linoleic acids, to which the oil owes its characteristic property of absorbing oxygen and thereby becoming converted to linoxin—the characteristic rubber-like product of "dried" linseed oil.

The presence of certain metals facilitates this process, and these metals are incorporated with the oil by heating their compounds with the raw oil. Recent investigations indicate that the three metals practically most effective for this purpose are lead, manganese and cobalt, and consequently advanced manufacturers have generally abandoned the use of other compounds.

It will be noted that the liquid portion of our paint contains 85 per cent of linseed oil. The fact is significant, for while linseed oil leaves something to be desired when we contemplate the ideal paint, it is nevertheless the most satisfactory paint oil for general use known to us up to the present time.

The remaining fixed oil in our formula is **China wood oil**, of which only 2 per cent is present. China wood oil is comparatively a recent addition to the raw materials of paint and varnish manufacture. It is pressed from a nut grown on a tree (*Aleurites cordata*) indigenous to the Yangtze Valley in China. The variety producing the oil nut is known to the Chinese as ying tzu tung (apple fruit Tung), and the tree is cultivated by the Chinese farmer for its oil. It grows to a height of about 25 ft., bears large green leaves, small pinkish flowers and large green fruit somewhat resembling an apple. The seeds are large and poisonous, and from them the oil is obtained. The machinery used is primitive, consisting essentially of a wooden press operated by wedges. The oil is traded, along with other agricultural products, to merchants at Hankow, Fatcheu and Canton. It has been used in China for ages, much for the same purposes as linseed oil is used in this country, and it is said that the extracted seed residues are the raw material for the manufacture of India ink.

But little is as yet known generally regarding the chemistry of this oil. It has drying properties similar to a certain extent to those of linseed oil, and the rate of hardening is accelerated by the same agencies that promote the oxidation of the more familiar oil. The chemical process appears, however, to differ, since while linseed oil hardens progressively from the surface inward, China wood oil seems to harden or set simultaneously throughout. This peculiarity led to rather expensive disasters in the earlier attempts to utilize the oil in this country. The drying salts are incorporated in practice at a comparatively low temperature, but in these earlier experiments the oil was treated at the temperature common in the treatment of linseed oil, with the result that the entire batch suddenly thickened to a consistency of rubber in the kettle.

While the use of this oil is still the subject of experiment, it has established itself an important place in the varnish industry, and is making rapid strides in the paint industry, especially in the manufacture of flat interior wall paints.

The two volatile ingredients of our formula are asphaltum spirits and turpentine. **Asphaltum spirits** is one of the lighter products of petroleums having an asphaltum base. It corresponds to the benzine which is produced from petroleums with a paraffin base.

The chemistry of these hydrocarbons, while interesting, plays no part in the chemical structure of the paint film, since their office is purely mechanical and they disappear completely in the drying of the paint. As is well known, the petroleums found in some localities yield, on distillation at high temperatures, residues containing paraffin, while similar oils from other localities yield asphaltums as residues. The best known petroleums of the latter class are those produced in Texas, California and the Island of Borneo. Petroleums are distilled by fractionating, the products passing over at the lower temperatures being classified progressively as petroleum ethers, naphthas and gasolines and benzines. At still higher temperatures the illuminating oils pass over, followed by the lubricating oils. Asphaltum spirit is the benzine of the asphaltum petroleums. It boils at a higher temperature than the corresponding paraffin product, has a higher specific gravity and is, on many accounts, far preferable as a volatile ingredient of paints. I personally believe that the formula before us is mechanically improved by the presence of this material and I am convinced that it is in no way injured by it.

Turpentine is the essential oil of certain pines, principally *Pinus Australis*, growing over large areas of our Southern States. It is distilled in a current of live steam from the sap of this tree, the residue being rosin. The industry, owing to the character of the labor available in the pine districts, is crude and wasteful both to the timber involved and to the product, though more conservative methods are coming into use through the effort of the United States Department of Agriculture.

The negro workman in a turpentine orchard cuts a so-called "box" on one side of the tree, in which the sap collects, and from which it is from time to time dipped and carried to the still. As the flow of sap decreases, the bark is removed and the wood scarified higher and higher above the "box." In the larger trees

several boxes are cut at different points on the circumference, weakening and in time killing the tree. The crude sap or gum is charged into a still with water, and on heating, the volatile turpentine passes with the steam to a worm condenser. The turpentine is decanted from the condensed steam on which it floats.

Turpentine in paint probably acts in two ways: First, as a volatile thinner, of which the effect is purely mechanical; and secondly, as a conveyor of oxygen, perhaps catalytically. At any rate it was the conclusion of a French technical commission who investigated the subject, that turpentine hastens the drying of paint to an extent not accounted for by its volatility.

The principal turpentine forests of to-day are located in Florida, southern Georgia and Louisiana, the immense forests that formerly covered vast areas in North and South Carolina and northern Georgia having been largely destroyed by the wasteful methods in vogue. Another form of turpentine has appeared in the market during comparatively recent years. It is familiarly known as wood turpentine, being produced, by various methods of distillation, from pine wood wastes. When properly prepared and purified, there appears to be no practical difference in its properties as a paint vehicle from those of sap turpentine.

The remaining liquid ingredient of our formula is **Japan dryer.** This consists essentially of the linoleates of lead and manganese, with a small percentage of Kauri gum. It is prepared by boiling linseed oil with the proper percentages of compounds of manganese and of lead, adding thereto a certain quantity of melted Kauri gum, and reducing the product while warm, with turpentine, benzine or a mixture of the two. The lead compound used in this dryer is red lead and the manganese compound is the black oxide, while the reducing agent is turpentine and Texas benzine—asphaltum spirit.

The manufacture of red lead leads us at once into the mining regions of the West, where in some districts lead is produced from practically pure ores, while in others it must be separated from its commingled silver, zinc, etc.

For the manufacture of the so-called Dutch process white lead it is necessary to have the metal free from silver, manganese and iron; but for the manufacture of the ordinary oxides purity is not so important. The metallic lead comes from the smelter in the form of pigs, which are melted in a low, flat oven in which the lead spreads out in a thin layer and is mechanically worked so as to expose continually fresh surfaces to the action of the air. The product is the monoxide of lead —massicot. This oxide is ground with water to remove metallic particles, which are returned to the furnace, while the oxide is collected in settling tanks. If the temperature in the furnace rises too high it becomes litharge—crystalline lead monoxide—which cannot be further oxidized.

The amorphous monoxide, being further treated in the same or a similar oven, at a low red heat, with free access of air and constant stirring, gradually takes up more oxygen and is converted into red lead—a combination of the monoxide and the dioxide, in the proportion of about two parts of the former to one of the latter. The product is usually stated as having the formula Pb_3O_4, but commercial red lead is, as noted, a mixture of oxides rather than a definite chemical compound.

The black oxide of manganese, known to mineralogists as pyrolusite, is a natural product, of which the principal sources of supply are in the Caucasus Mountains, in the Hartz Mountains and elsewhere. Chemically, it is the dioxide of the metal manganese. The miners are the wild mountaineers of eastern Europe, and the mineral before it reaches America, passes through southern Russia, the Black Sea, the Dardanelles, the Mediterranean and so across the Atlantic. For the use of the varnish and dryer manufacturer it is subjected to mechanical purification.

These two metallic oxides readily replace the glycerin in linseed oil at moderate temperatures, forming oleates and linoleates, while the glycerin is decomposed and driven off.

The addition of a resin—in this case Kauri gum—at a moderately high temperature also probably induces the formation of resin acid compounds of the metals.

The driers made with lead and with manganese have sharply distinguished properties, of which advantage is taken by the well-informed manufacturer, who knows that certain proportions of the two yield better average results than either alone. He also carefully calculates the percentage of the metal in the drier to the oil to be oxidized. Kauri gum, besides helping the quality of the japan, has also been shown by experience to serve a useful purpose in paints containing high percentages of zinc oxide. It is found only in New Zealand, where ancient forests of the tree which produced it—the *Dammara austaralis* and other varieties of Dammara—have been buried for ages in the earth. It is mined systemmatically by trenching and is cleaned, sorted and classified by hand.

Components of Pigment

We have now briefly covered the liquid portion of our formula and in the course of our survey have gone to North Dakota for flaxseed, to Florida for turpentine, to Texas for benzine, to China for wood oil, to Colorado and Montana for lead, to the Caucasus for manganese, and to New Zealand for Kauri gum. Even at this point we may begin to see that for this ordinary can of mixed paint the manufacturer has been under the necessity of calling upon many industries, several races and different quarters of the globe. It is no less so with the remaining items of our formula and the package in which it is sold. **Lead hydrocarbonate** is the first named of the solid ingredients. In this case it happens to be Dutch-process white lead.

Lead hydrocarbonate or basic lead carbonate is a molecular combination of the hydroxide and the carbonate of lead in about the proportion of two parts of the latter to one of the former, though these proportions are only approximated in actual practice. The accepted formula, however, is $2PbCO_3$, PbH_2O_2. Of the three processes used to any extent for the manufacture of this product, two employ acetic acid in an intermediary step of the chain of reactions, while the third dispenses with it.

The *old Dutch process,* so called—though it has undergone great improvement in English and American practice—starts with desilvered lead pigs, known in the trade as "soft lead." These are melted, and the molten lead is distributed in shallow molds on an endless-chain belt. The molds give the metal the form of a flat circular grating or buckle about 3/16 in. thick by 5 in. in diameter. These buckles are packed into earthenware pots, having at their bottom shallow wells containing each about half a pint of vinegar or dilute acetic acid.

The charged pots are arranged in tiers between layers of spent tan bark, where they are allowed to remain undisturbed for about 130 days. By the fermentation of the tan bark heat is generated and carbonic acid liberated. The heat vaporizes the acetic acid, which attacks the lead, coating the buckles with basic lead acetate. This in turn is attacked by the carbonic acid, producing the basic carbonate and liberating neu-

tral lead acetate, which attacks the metallic lead beneath, producing again the basic acetate.

The process thus continues progressively until most of the buckle has been altered to the basic carbonate. The buckles being removed from the pots are subjected to mechanical treatment which separates the corroded from the uncorroded portions. The white lead after being ground, washed, floated and dried, enters commerce as dry white lead. The special characteristics of corroded white lead are its excellent working properties and low oil consumption, giving a high degree of opacity or color-body in the finished paint.

The second process, commonly known as the "*quick process*," also starts with desilverized pig lead. This is melted and finely comminuted in a steam blast, and the granulated product is charged into large, slowly revolving wooden drums, where, after being moistened with dilute acetic acid it is subjected for some hours to the action of purified carbonic acid gas from burning coke. The slow revolution of the drums insures the exposure of the entire mass to the action of the gas.

The chain of chemical processes involved is probably identical with those described for the old Dutch process. The mechanical treatment of the crude corroded product is essentially the same. The finished product is more uniform in the size of particle than Dutch-process lead and finer in texture. This involves a larger oil consumption and a consequent decrease in opacity or color body of the completed paint.

The third process, known as the *mild process*, because of the fact that acetic acid is not used, is applicable to pig lead of any description. In this process, also, the metallic lead is finely comminuted in a steam blast. In both this and the preceding process there is a preliminary surface hydration produced by the action of the water vapor on the lead particles. The finer particles are charged into revolving drums containing water and there subjected to the action of air under low pressure for several hours. The lead is thereby converted into the basic hydroxide. This hydroxide is then subjected in similar drums to the action of purified carbonic acid gas for the requisite time, until the conversion to the basic carbonate has been carried to the proper point. The product is extremely white, uniform and pure, requiring only water-floating and drying to fit it for use.

The second pigment of our formula is **basic lead sulphate** or basic sulphate white lead. This is a sublimation product, and is produced directly from the native ores of Missouri—lead sulphide—by oxidation at a high temperature in a current of air. The comminuted ore is charged in a special furnace with coal or other fuel and is subjected to a hot-air blast. The sulphide takes up oxygen, volatilizes and is carried through a series of cooling flues to fabric bags, in which it is collected.

This is the process in outline, though not in detail. The reaction involved is simple; the lead sulphide, PbS, takes up four equivalents of oxygen from the air being converted into lead sulphate, $PbSO_4$. At the same time it is also claimed, with much probability, that there is formed a certain proportion of the basic lead sulphate, $Pb_3S_2O_9$. At any rate analysis always yields an excess of oxygen, which is usually calculated to lead oxide, the percentage of which ranges from fourteen to twenty. The product, furthermore, always contains a small percentage (five to six) of zinc oxide, which comes from the zinc sulphide associated with the ores used.

It may be said in passing that lead sulphate produced in the laboratory is a very unsatisfactory pigment, exhibiting none of the characteristics of the "sublimed" white lead. The latter, on the other hand, is extremely useful, and in certain combinations has come to be regarded as almost indispensable. The particles of this pigment are extremely fine and uniform, approaching the particles of zinc oxide in this respect. As a pigment, it stands between corroded white lead and zinc oxide in most of its characteristics. Paints made with it chalk more freely than paints made with the former, but on the other hand, they retain their color better, and do not "check" so freely. Proper combination with zinc oxide restrains the characteristic chalking while the hardening peculiar to zinc is in turn restrained.

Our third pigment is **zinc oxide**. Zinc is peculiar in that it is the only metal in common use produced by distillation. It is volatile at an easily attainable temperature and advantage is taken of this fact in recovering the metal from its ores. The hot metallic vapor is also readily oxidizable, and if exposed to the air, will take fire, burning with a green flame to zinc oxide.

The oxide is produced by two different processes. One, known as the French process, taking advantage of the fact just mentioned, volatilizes the metal in a current of air and collects the resultant oxide in closed chambers.

In the other process, known as the American process, the oxide is produced directly from the ores. On the nature of the ore used depend the individual characteristics of the resultant oxide.

In this process the comminuted ores are mixed with powdered anthracite and charged into closed furnaces having perforated grate bars. Combustion is started in the anthracite and a blast of air is forced through the perforations in the grate. The heat smelts the ore and volatilizes the zinc, and the metallic vapors promptly combine with the oxygen of the blast, producing zinc oxide. This oxide is carried through a series of cooling flues and collected in fabric bags.

The particular oxide used in this formula is made from New Jersey ore, and on that account is of some interest. This ore is unique in that it occurs in commercially available quantities, nowhere else in the world. It is known as franklinite, and consists of the oxides of zinc, manganese, and iron in molecular proportions—crystallizing as a true mineral. It is closely associated in the vein with other compounds of zinc—the anhydrous silicate, the oxide, etc. A peculiarity of the product is that the oxide recovered is practically free from impurities, averaging over 99 per cent pure oxide. The oxides produced from the ores mined in other localities usually contain from 5 to 15 per cent of lead sulphate, due to the presence of lead sulphide in the vein.

The characteristics of zinc oxide are too well known to require extended comment. It is the finest and whitest of all white pigments; is chemically quite stable, the only chemical changes possible in practice being to the sulphide or to the carbonate, while is also white. It is bulky and hence carries a high percentage of oil in the finished paint; and finally, when properly used, it is very durable. One is fairly safe in saying that if oxide of zinc had not been introduced as a pigment, there would have been no prepared paint. It was produced as a commercially available pigment, in answer to a demand that had been voiced in Europe from the closing years of the eighteenth century, to the time of its introduction about the middle of the nineteenth. This demand for a non-poisonous white pigment finally received a satisfactory response from a contracting painter of Paris, Le Claire, who was also celebrated as a philanthropist and is known to this day as "the father of profit sharing." Practically every great chemist of Europe from Lavoisier to Faraday had his try at the problem.

Our next pigment is **magnesium silicate** in the form

of asbestine. This product comes principally from Canada. Its usefulness in the paint formula depends entirely upon its physical form, which is acicular or rod-like. Its office in the paint film has been compared to that of the hair in plaster or the rods in reinforced concrete. It is without special value either for opacity or protection, but aids in holding the materials in suspension and very probably also in resisting stresses in the dried paint film.

Our fifth solid ingredient is **calcium carbonate**—in this case a natural product from Missouri—a dolomitic crystalline rock, finely ground for the purpose. Calcium carbonate, as used in paint manufacture, comes to us in two forms. Whiting, Paris white, etc., are the pulverized and floated chalk supplied principally by the chalk cliffs around Dover, England; the calcareous skeletons of innumerable diatoms that once populated the waters of an ocean covering that portion of the earth, ages before the advent of man; while the product used in this formula is from a similar geological source, but in succeeding epochs subjected to heat and pressure, which gave it a crystalline structure. As a rule manufacturers in selecting from these two forms are governed by the conditions; if the remaining inert pigments are crystalline, Paris white is selected; if not, then the so-called mineral primer is preferred.

Either will neutralize any free acid in the paint, but the mineral primer will in addition give the "tooth" which is thought desirable in the manual work of painting. The only other crystalline pigment in our formula is the asbestine, so mineral primer rather than a form of chalk has been selected for this formula.

Barium sulphate is the next on our list, and is used in the form of the chemical precipitate—blanc fixe. The sulphate of barium in the form of barytes is a natural, crystalline product, which retains its crystalline form, no matter how finely comminuted.

It is found associated with lead, zinc and other ores in most mineral regions. That used in the United States, however, comes principally from Missouri and the Alleghenies in Central Virginia, Tennessee, etc.,—Missouri furnishing the larger proportion. There its production is in the hands of farmers who collect and cart it to the railroads in the fall and winter, to be manufactured into pigment at St. Louis and neighboring points. In the Allegheny regions the mineral is procured by mining.

Blanc fixe is produced by transforming the natural product into a soluble compound and precipitating it from dilute solution with sulphuric acid or a soluble sulphate. The product is chemically identical with barytes, but physically quite different, being very finely divided and amorphous.

Silicate of alumina is the next ingredient of our white base. Technically it is a washed and floated China clay, naturally produced by the disintegration of certain feldspars, the soluble potassium and sodium salts having been washed away. The percentage here used is small, but it has a physical influence on the suspension of the other pigments, in the brushing qualities of the paint and on the quality of the paint film.

The remaining ingredients of our formula are the colors required to produce the desired tint. They have no influence on the quality of the paint. The yellow in this combination is **lead chromate**—chrome yellow. It is produced by the reaction of a soluble chromium salt, usually sodium bichromate, on a soluble lead salt, usually lead nitrate, both in solution. The neutral chromate of lead $PbCrO_4$, being insoluble, is precipitated. The production of this familiar pigment again takes us far afield. The chromium used in making the chromates is obtained from an ore of iron known as chromite. It is a chromate of iron, having the composition $FeCr_2O_4$. It is found in small quantities in Pennsylvania, Maryland, California and elsewhere in the United States, but the main sources of supply are Asia Minor and Australia. Large quantities of these ores are imported into England, Germany and the United States for the sole purpose of manufacturing the chromium salts of potassium and sodium. The process is intricate and difficult, so that the manufacturers are few in number. There is also some demand for the mineral in the manufacture of special steels.

The remaining pigment is **Prussian blue**—the potassio-ferro-ferri-cyanide of iron. This material brings us once more into the field of organic chemistry, the non-metallic component of the blue being cyanogen, which is most familiarly known as a component of hydrocyanic or prussic acid and the cyanides of potassium, etc. The chemical composition of the color is indicated by the formula $K_2Fe_2 2FeC_6N_6$.

The cyanides are obtained from organic wastes containing carbon and nitrogen, principally the residues from gas works.

In practice, in the manufacture of chrome green as used for tinting in the present instance, the colors are precipitated simultaneously from solution, either with or on the base, which in this case is the blanc fixe shown in the formula.

The Paint Factory

We have now glanced hastily at the characteristics of our several ingredients, but they are still only raw materials and require a long series of mechanical operations before our can of paint will be ready for use, not to mention the detailed work of the chemist to determine the quality of the materials themselves.

A modern paint factory is a complicated institution, and in the limits of such a paper as this can only be touched upon briefly and hastily. Power in the most modern plants is generated at a central point and is distributed to the units in the form of electrical energy. As a rule the raw materials are elevated to the highest point in the plant, so that the product, in its several steps toward completion, may fall by gravity from each point to the next in the process.

The dry pigments are ground separately to the form of a paste with linseed oil. The various components of the white base are then thoroughly incorporated with more oil, the whole is then mixed with the rest of the oil and the remaining thinners in a mechanical agitator, the tinting colors being added either here or at the preceding step, and the exact tint is attained by addition on the judgment of the expert tinter. The finished paint is measured mechanically into tin cans, which are also soldered and labeled by machinery, and finally these cans are packed in cases holding a given number and guarded from injury by sawdust placed between them. The boxes are then nailed, shut, marked and shipped to the distributors. This is the mechanical routine in the barest outline; but we may observe that it involves the use of building materials, fuel, copper wire, tinplate, paper, printing ink, paste, box lumber, sawdust, wire nails, etc.

The manufacture of tinplate is an important industry in itself, involving a branch of the steel industry in the production of the plates for this use. These plates are cleaned by chemical means, heated, and coated with metallic tin by dipping in a bath of the molten metal. To obtain the tin for this use we must again go to distant regions. The ores are found in small quantities in various parts of the United States.

Cornwall, from the time when the Phoenicians traded to Britain for tin to the days of the first McKinley tariff,

was the chief source of the world's tin supply. But the drain finally told on the natural resources, and the bulk of the tin consumed to-day comes from the Straits of Malacca and from Australasia. In the former locality it is recovered by placer mining methods and in the latter by the usual methods of underground mining. The ore is found in two forms, as the oxide, casserite, and as the sulphide, stannite, in which latter form it is associated with iron. The smelting of the ore for the metal is done principally in England and other parts of Europe.

The paper for our label is a product of sulphite wood pulp, as is most of the paper used for advertising paint. We need not enter further into this subject except to note that our industry involves also the paper manufacturing industry.

Similarly we may note in passing that the printing ink manufacturer and through him the lampblack manufacturer, the color maker and the varnish manufacturer are involved.

Finally, in the consumption of paste, we return once more to the farmer, on whom we called in the first instance for our linseed oil.

The manufacture of this important product, paint, formerly based on empirical experience, is more and more coming under the jurisdiction of the trained technical man. To him we owe the fact that we have now at our command special paints for many special purposes: Flat wall paint for interior decoration; paint for the protection and decoration of concrete; rust-inhibitive paint for the preservation of steel structures, etc.

We know a great deal about paint, in a general way. There is a mass of experimental data on hand to be correlated, interpreted and made the basis of broad general laws. To this phase of the subject the trained paint technologists are now turning their attention.

In conclusion, permit me to say that there is no subject more interesting or more important to us as citizens or as property owners. As citizens we owe largely to paint the beauty and wholesomeness of our surroundings and as property owners, the preservation of our structures.

Educational Bureau, Paint Mfrs. Asso. of U. S.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

The Tonopah Plant of the Belmont Milling Co.—Cyanide practice at Tonopah was described in a paper by A. H. JONES, superintendent of mills for the Tonopah-Belmont Development Company, at the A. I. M. E. meeting in San Francisco. The cost of the plant, designed to handle 500 tons of ore per day, is shown in Table I.

A flow-sheet is shown in Fig. 1, giving details of machinery used.

The ore is crushed to 1-in. size and automatically sampled and weighed.

The consumption of wearing parts in the crushing plant amounts to 0.0325 lb. per ton of ore at an expense of $0.00555.

Sixty 1250-lb. stamps crush through 4 and 6-mesh Taylor ton-cap screens at the rate of 8.88 tons per stamp per 24 hours. Five tons solution is used per ton of ore stamped. The solution has a cyanide strength of 5 lb. and a lime strength of 1 lb. Metal consumption in stamping is as follows: Forged steel dies, 0.207 lb. per ton of ore; chrome steel shoes, 0.179; discarded iron in dies and shoes equals 0.064 lb. and 0.108 lb. per ton of ore respectively, making a total of 0.553 lb. per ton of ore, of which 0.386 lb. is consumed and the balance discarded. Average service for cam shafts has been 27,214 tons stamped.

Thermit welding of cam shafts has been tried at a cost per shaft of $42.53.

TABLE I.—CONSTRUCTION COSTS, BELMONT MILL

	Excavation Concrete Walls and Foundations	Floors and Machinery Foundations	Buildings: Frames	Buildings: Covering	Machinery, Including Erection, Piping, Wiring, Belting, Etc.	Totals
Crusher plant	$5,760 72	$2,527.58	$2,230 72	$1,476.69	$21,174 96	$33,170 67
Inclined conveyor	166.41	238.02	1,771.75	585 19	3,620 79	6,382.16
Battery bins	399 00	489.70	.	2,067 69	3,475 14	6,431.53
Stamps	. . . .	8,797.82	. .	. . . .	36,873.06	45,670.88
Tube mills and classifiers	. .	3,180 95	.	.	40,127 89	43,308.84
Callow cones	.	26.02	.	.	856.63	882.65
Concentrating plant	. . . .	1,663.23	. .	. .	11,356 35	13,019 58
Concentrate house	76 80	449.69	354 80	623 27	602 10	2,106.66
Dorr thickeners	. .	11,297.98	. .	. .	15,034 53	26,332 51
Circulating system	. .	147.81	. .	. .	6,846 05	6,993 86
Air agitation	261 71	3,987.80	. .	. .	25,257 89	29,507 40
Clarifying	. . . .	1,829.63	. .	. .	8,573 87	10,403.50
Precipitation system	395.00	44 05	. .	. .	29,581 02	30,020.07
Briquetting plant	. . . .	. .	. .	. .	1,589 49	1,589.49
Air compressor	. . . .	1,084 39	. .	. .	7,094 52	8,178 91
Filter plant	. . . .	4,456.68	. . . .	. .	30,104.50	34,561.18
Refinery	2,473.84	1,552.23	2,200 17	2,292 80	7,548.79	16,067.83
Boiler plant and fuel-oil system	571.56	90.97	401.25	531 11	7,606 28	9,201.17
Tank-heating system	. . .	9.56	. . . .	. . .	3,362 39	3,371.95
Transformer house	91.83	101.05	428.69	213.07	4,804.89	5,639.53
Lime house	11.00	. . . .	. . . .	753.30	305 85	1,070.15
Machine shop	1,297.66	843.01	1,138.73	1,191 93	339.36	4,810 69
Storeroom	511.55	1,509 60	1,305.84	1,315.78	152.04	4,794 81
Inclined railway	133.25	. . . .	432.70	203.41	379 51	1,148 87
Mill building	39,645 45	6,757 60	45,493.48	19,607.14	9,020.51	120,524 18
Total	$51,795 78	$51,085 37	$55,758 13	$30,861 38	$275,688 41	$465 189,07

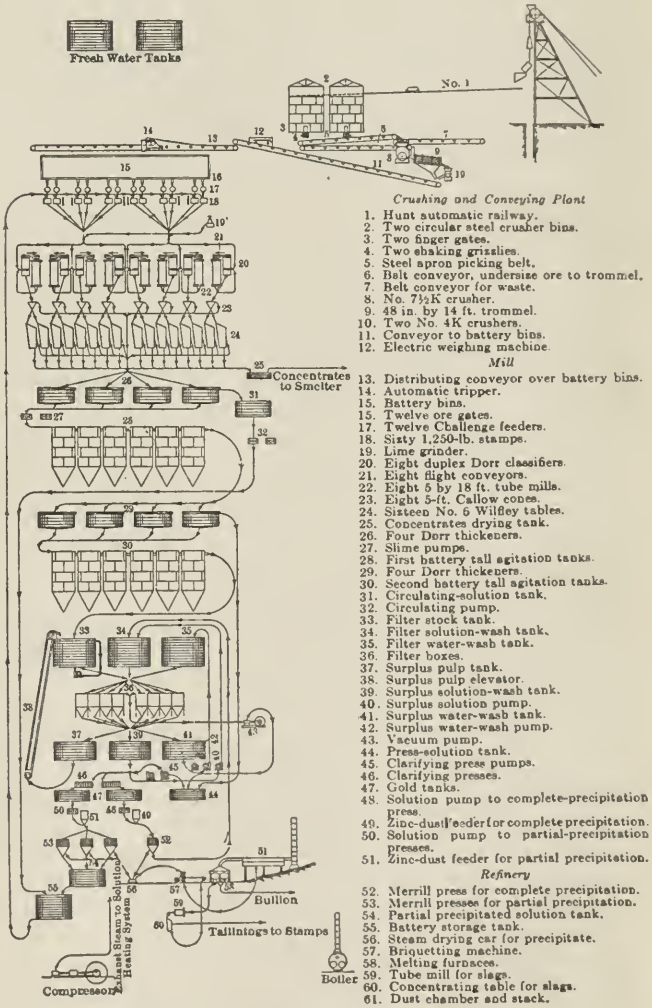

Fresh Water Tanks
No. 1
Concentrates to Smelter
Bullion
Tailings to Stamps
Compressor
Boiler
Crushing and Conveying Plant
1. Hunt automatic railway.
2. Two circular steel crusher bins.
3. Two finger gates.
4. Two shaking grizzlies.
5. Steel apron picking belt.
6. Belt conveyor, undersize ore to trommel.
7. Belt conveyor for waste.
8. No. 7½K crusher.
9. 48 in. by 14 ft. trommel.
10. Two No. 4K crushers.
11. Conveyor to battery bins.
12. Electric weighing machine.
Mill
13. Distributing conveyor over battery bins.
14. Automatic tripper.
15. Battery bins.
16. Twelve ore gates.
17. Twelve Challenge feeders.
18. Sixty 1,250-lb. stamps.
19. Lime grinder.
20. Eight duplex Dorr classifiers.
21. Eight flight conveyors.
22. Eight 5 by 18 ft. tube mills.
23. Eight 5-ft. Callow cones.
24. Sixteen No. 6 Wilfley tables.
25. Concentrates drying tank.
26. Four Dorr thickeners.
27. Slime pumps.
28. First battery tall agitation tanks.
29. Four Dorr thickeners.
30. Second battery tall agitation tanks.
31. Circulating-solution tank.
32. Circulating pump.
33. Filter stock tank.
34. Filter solution-wash tank.
35. Filter water-wash tank.
36. Filter boxes.
37. Surplus pulp tank.
38. Surplus pulp elevator.
39. Surplus solution-wash tank.
40. Surplus solution pump.
41. Surplus water-wash tank.
42. Surplus water-wash pump.
43. Vacuum pump.
44. Press-solution tank.
45. Clarifying press pumps.
46. Clarifying presses.
47. Gold tanks.
48. Solution pump to complete-precipitation press.
49. Zinc-dust feeder for complete precipitation.
50. Solution pump to partial-precipitation presses.
51. Zinc-dust feeder for partial precipitation.
Refinery
52. Merrill press for complete precipitation.
53. Merrill presses for partial precipitation.
54. Partial precipitated solution tank.
55. Battery storage tank.
56. Steam drying car for precipitate.
57. Briquetting machine.
58. Melting furnaces.
59. Tube mill for slags.
60. Concentrating table for slags.
61. Dust chamber and stack.

FIG. 1—FLOW-SHEET OF BELMONT MILL

Lime is added at the tube-mills in the form of milk of lime, and about one-half the total quantity of lead acetate used is also added here. About 75 per cent of the pulp is ground to minus 200-mesh size. The cost of silex lining was $395.84. It had a life of eight months, grinding 15,533 tons of ore. The cost of this lining per ton reground was $0.0583; per ton of ore milled, 0.048. With Komata manganese steel lining the cost per ton reground was $0.0457. The Belmont type of ribbed lining made of hard white iron has shown a service of nineteen months, and a cost of but $0.0346 per ton reground.

It is estimated that this lining will last two years and show a cost of but $0.0173 per ton reground. Danish pebbles are most economical.

A simple and accurate method of figuring return tonnage from tube-mill to classifier, in accordance with the accompanying table of screen analyses, is as follows:

Mesh	Battery Discharge		Tube-Mill Feed		Tube-Mill Discharge		Dorr Overflow	
	Per Cent	Cumulative, per Cent	Per Cent	Cumulative, per Cent	Per Cent	Cumulative, per Cent	Per Cent	Cumulative, per Cent
+ 10	10.3	12.3	5.4	5.4	....	.....	....	.....
+ 14	10.0	20.3	5.2	10.6	....	.....	....	.....
+ 20	10.2	30.5	5.3	15.9	....	.....	....	.....
+ 28	11.3	41.8	5.9	21.8	....	.....	....	.....
+ 35	7.7	49.5	4.9	26.7	1.0	1.0	....	.....
+ 48	7.1	56.6	6.5	33.2	3.1	4.1	....	.....
+ 65	5.6	62.2	8.1	41.3	6.5	10.6	....	.....
+100	6.0	68.2	20.0	61.3	20.0	30.6	1.0	1.0
+150	6.6	74.8	24.4	85.7	28.6	59.2	12.5	13.5
+200	4.0	78.8	7.8	93.5	12.7	71.9	14.2	27.7
−200	21.2	100.0	6.5	100.0	28.1	100.0	72.3	100.0

Tons crushed per day, 500. Feed per mill, 62.5 tons.

In the battery discharge there was 41.8 per cent., or 26.12 tons, which did not show in the tube-mill discharge. This material was represented in total tube-mill feed by 21.8 per cent. As we know this 21.8 per cent is represented by 26.12 tons, 100 per cent of the feed amounts to 119.8 tons.

Total feed, tons	119.8
Initial feed, tons	62.5
Return feed, tons	57.3
Ratio of return to initial feed	0.92 to 1

Concentration is practiced mainly for the purpose of removing only the heaviest and most refractory mineral. This gives a clean product but not a close concentration. For the fiscal year ended Feb. 28, 1915, concentration represented 0.67 per cent by weight and 11.5 per cent in extraction of the precious metals.

Pulp thickening is done in Dorr continuous thickeners, and agitation in tanks of the Pachuca type. Originally only 5.5 sq. ft. of settling area per ton of ore was allowed, but owing to changes in the ore this has had to be increased. Trays introduced into the Dorr thickeners increased the settling area to 8.47 sq. ft. They have given no serious troubles and have increased the capacity of the two thickeners in which they were installed about 75 per cent.

After continuous agitation the pulp is thinned by adding barren solution, and again thickened and agitated. This removes a large portion of the dissolved gold and silver and relieves the filters of this work. Solutions are heated to about 90 deg. Fahr. by steam coils placed in the air-lifts of the agitators. Extraction is improved about 2 per cent by use of warm solutions. The agitators are 15 ft. by 45 ft., and require 67½ cu. ft, of free air per minute at 30 lb. pressure.

A 250-leaf vacuum filter plant, constructed on the half-gravity system, is used for final displacement of solution from slime. Precipitation is by zinc dust. Only enough solution is completely precipitated to make the final barren-solution wash at the filters. The balance is precipitated to a value of 10 cents per ton and used in diluting at Dorr thickeners, tube-mill feed solution and for table wash. Zinc consumption is 0.7808 oz. per ounce of bullion. Precipitate is briquetted with 2.45 per cent borax, 6.05 per cent soda and 6 per cent sand and melted, the bullion averaging 93.23 per cent gold and silver.

Extraction is 96.2 per cent of the gold and 93 per cent of the silver.

The accompanying table shows the dissolution of gold and silver through the different steps in the process:

	Assays			Per Cent of Extraction in Each Department			Per Cent of Total Extraction in Each Department		
	Au	Ag	Value	Au	Ag	Total	Au	Ag	Total
Battery heads	0.32	32.1	$25.66	...	...	....	...	...	....
Battery discharge	0.21	30.4	22.44	...	...	....	...	...	....
Extraction in battery	...	...	....	34.4	5.3	12.5	34.4	5.3	12.5
Battery discharge	0.21	30.4	22.44	...	...	....	...	...	....
Dorr classifier overflow	0.08	27.1	17.86	...	...	....	...	...	....
Extraction in tube mills	...	...	....	62.0	10.8	20.4	40.7	10.28	17.9
Classifier overflow	0.08	27.1	17.86	...	...	....	...	...	....
Table tailings	0.06	24.2	15.72	...	...	....	...	...	....
Extraction by concentration	...	...	....	25.0	12.0	8.9	6.0	9.0	8.34
Table tailings	0.06	24.2	15.72	...	...	....	...	...	....
Agitator heads	0.05	21.2	13.72	...	...	....	...	...	....
Extraction lower thickeners	...	...	....	16.6	12.4	20.0	3.1	9.33	7.8
*a*Agitator heads	0.054	18.9	12.42	...	...	....	...	...	....
*a*No. 6 agitator	0.02	4.85	3.31	...	...	....	...	...	....
Extraction first six agitators	...	...	....	60.0	74.3	73.3	9.4	50.99	40.57
*a*No. 6 agitator	0.02	4.85	3.31	...	...	....	...	...	....
No. 7 agitator	0.015	4.2	2.82	...	...	....	...	...	....
Extraction upper thickeners	...	...	....	25.0	13.3	14.8	1.2	2.0	1.9
No. 7 agitator	00.15	4.2	2.82	...	...	....	...	...	....
*a*Filter stock	0.014	2.8	1.96	...	...	....	...	...	....
Extraction second six agitators	...	...	....	6.6	33.3	30.5	0.3	4.3	3.3
*a*Filter stock	0.014	2.8	1.96	...	...	....	...	...	....
*a*Filter discharge	0.01	2.3	1.58	...	...	....	...	...	....
Extraction in stock tank and filters	...	...	....	28.6	18.0	10.3	1.25	1.56	1.48

*a*Samples are averages for 30 days, taken from assay records. Silver figured at 60c. per ounce for values.

Milling Costs for the Fiscal Year 1914–15, per Ton of Ore Treated

	Labor	Supplies	Power	Total
Crushing and conveying	$0.036	$0.020	$0.010	$0.068
Stamping	0.056	0.155	0.096	0.307
Classifying	0.014	0.002	0.006	0.022
Tube milling	0.032	0.102	0.230	0.364
Thickening	0.024	0.028	0.003	0.055
Concentrating	0.028	0.042	0.008	0.078
Agitating slime	0.050	0.764	0.007	0.821
Filtering and discharging	0.061	0.083	0.027	0.171
Precipitation	0.028	0.086	0.020	0.134
Assaying	0.009	0.005	0.000	0.014
Refining	0.017	0.024	0.002	0.043
Lighting	0.001	0.001	0.008	0.010
Shift bosses	0.036	0.000	0.000	0.036
Watchman	0.012	0.000	0.000	0.012
Surface and plant	0.015	0.006	0.000	0.021
Totals	$0.419	$1.318	$0.419	$2.156

Segregation of Supplies Used

	Quantity per Ton	Cost per Ton
Hydrochloric acid	0.17 lb.	$0.0078
Belting	.....	0.00336
Cyanide	3.52 lb.	0.601
Conveyor parts	.....	0.0004
Crusher parts	.....	0.0126
Lead acetate	0.366 lb.	0.033
Laboratory supplies	.....	0.003
Lime	5.47 lb.	0.041
Fuel oil	2.5 gal.	0.109
Pump parts	.....	0.011
Pebbles	4.16 lb.	0.057
Tube-mill lining	.....	0.023
Zinc	0.952 lb.	0.072
Refinery fluxes	.....	0.008
Battery shoes	0.287 lb.	0.0135
Battery dies	0.271 lb.	0.0148
Water (other than mine)	.....	0.165
Miscellaneous	.....	0.14254
Total	.....	$1.318

Cyanide Practice of Churchill Milling Co.—The mill of the Churchill Milling Co. is situated at Wonder, Nev., 55 miles from Fallon, the nearest railroad point. Operations for the year ended Sept. 30, 1914, were described by E. E. CARPENTER in a paper before the American Institute of Mining Engineers in San Francisco. A flow-sheet is given in Fig. 2.

The ore treated is an unusually tough and hard oxidized quartz containing a small quantity of sulphides, rich in both gold and silver. The mill is built on a 30 deg. slope, and contains equipment in the following order:

1, 10 by 16 in. Blake crusher.
10, 1,400-lb. stamps.
1, 6 ft. Trent Chilean mill.
1, Dorr duplex classifier.
1, 5 by 22 ft. tube mill.
1, 24 by 14 ft. Dorr thickener.
4, 15 by 45 ft. Pachuca type agitators.
1, 28 by 10 ft. Dorr thickeners.
1, 28 ft. by 14 ft. stock tank with stirrer.
2, 8 by 11 ft. 6 in. Oliver filters.
5, Zinc boxes.
2, Melting furnaces.

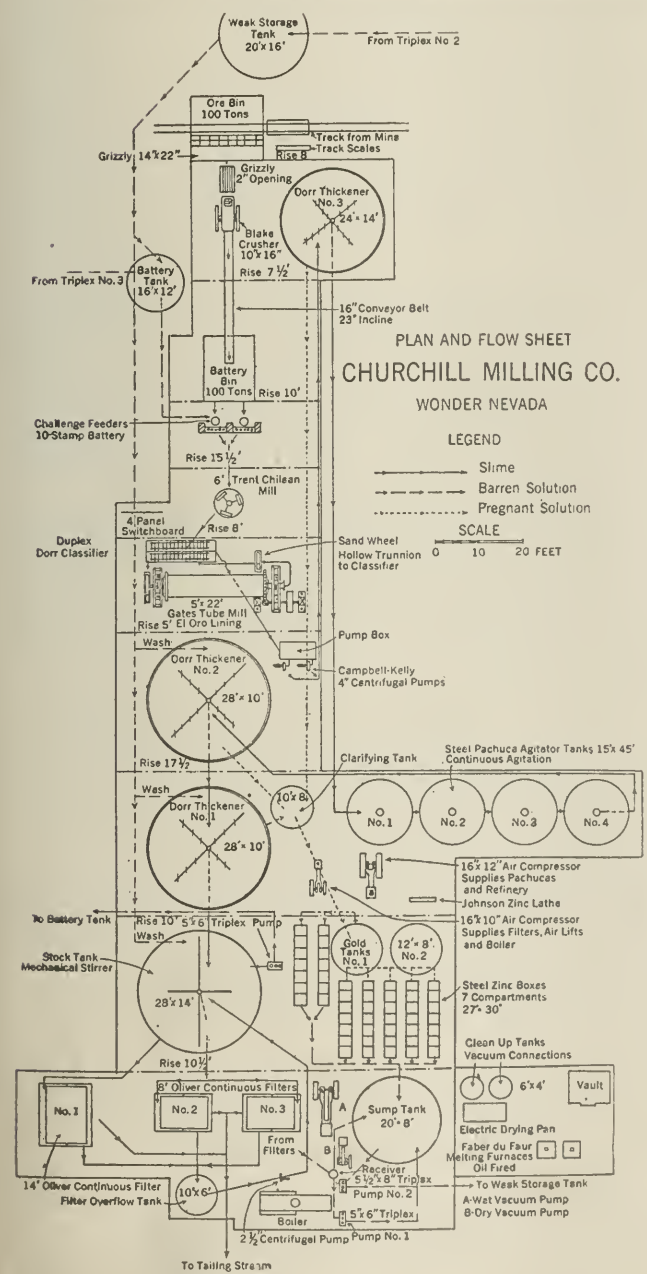


FIG. 2—FLOW-SHEET OF CYANIDE PLANT, CHURCHILL MILLING COMPANY

The annual report for 1914 shows a gold recovery of 95.1 per cent and a silver recovery of 92.4 per cent, or 93.2 per cent of the gross value. The average value of mill feed was 0.216 oz. gold and 19.48 oz. silver per ton.

TABLE I.—TONNAGE, COST AND RECOVERY DATA

Months	Tons per Month	Tons per Day	Total Direct Cost	Cost to Date	Gold Recovery, per Cent	Silver Recovery per Cent	Value Recovery, per Cent
Oct., 1913	4,160	134.2	$2 825	$2 825	95.3	92.8	93 6
Nov., 1913	4,032	134.4	2.852	2.838	94.2	92.9	93 7
Dec., 1913	4,103	132.4	2.812	2.830	94.3	93 4	93.7
Jan., 1914	3,357	108.3	3.189	2.906	95 2	92.1	92 5
Feb., 1914	3,254	116.2	2.861	2.898	93.8	93.6	93.7
March, 1914	4,350	140.3	2.567	2.836	94 8	93.7	93.9
April, 1914	3,730	124 3	2.604	2.804	95.3	92.2	93.1
May, 1914	4,217	136.0	2.598	2 777	94.3	91.1	91.2
June, 1914	4,200	140.0	2.521	2.746	95 6	89.4	91.7
July, 1914	4,392	141.7	2.781	2.750	96.3	90.6	92.1
August, 1914	4,440	143.2	2.657	2 739	97.3	93.4	94.3
Sept., 1914	4,335	144.5	2.771	2.743	97.3	92.7	94.0
Averages or totals	48,570	133 1	2 743	2.743	95.1	92 4	93.2

Stamps weighing 1400 lb. crush through ⅜-in aperature. Using chrome steel shoes and dies the consumption of steel per ton of ore ground was: Shoes, 0.232 lb; dies, 0.107; total, 0.339 lb.; cost per ton, $0.018.

In a Trent 6-ft. Chilean mill the average consumption of chrome steel was 0.5 lb. per ton of ore ground, costing $0.034. El Oro lining in a 5-ft. by 22-ft. Allis-Chalmers tube-mill cost $0.022 per ton ground, based on twelve months' operation with the liners still in use and worn practically smooth, with a prospect of three months' more use. Consumption of pebbles was 3.39 lb., costing $0.08 per ton of ore ground.

On an average tonnage of 133 per day, a 14-ft. by 24-ft. Dorr thickener takes care of the entire flow, giving 3.4 sq. ft. of settling area per ton of ore thickened.

Silver goes into solution very readily. Part of the lime and lead acetate is added at the Challenge feeders and the balance at No. 1 agitator. Sodium cyanide is added at No. 1 agitator.

The following table gives average extractions as obtained at different points in the process:

	EXTRACTION IN TANKS		TOTAL EXTRACTION	
	Gold, per Cent	Silver, per Cent	Gold, per Cent	Silver, per Cent
Up to No. 1 agitator	....	....	76.5	72.2
Disch. from No. 1	9.7	11.5	86.2	83.7
Disch. from No. 2	4.6	5.0	90.8	88.7
Disch. from No. 3	2.8	2.8	93.6	91.5
Disch. from No. 4	0.9	1.2	94.5	92.7
Filter	1.4	0 5	95.9	93.2

A saving of 0.23 lb. of cyanide was made by changing the method of washing the cake on the Oliver filter, using water on both ascending and descending sides, instead of barren solution on the former and water on the latter. In order to prevent excessive dilution of solution by this double use of water, a rubber apron is placed against the cake on the ascending side to divert the surface water to the slime-discharge launder. Similarly on the descending side an iron apron 18 in. wide was placed so that its upper edge was just above the blow-off section. This apron scraped off about 1/16 in. of the cake surface and removed considerable wash water, diverting the pulp to the usual discharge launder without interfering with the regular operation of the blow-off. This method makes it possible to keep the cake covered with a sheet of water on both sides without allowing an excessive amount to enter mill solution. Sampling and assaying of filter tailings shows a loss of

0.85 lb. cyanide per ton of ore, and a loss of soluble gold and silver of $0.18 per ton of ore.

Precipitation on zinc in boxes shows an average efficiency of 95.2 per cent, the average value of head and tail solutions being $2.227 and $0.107 respectively. The precipitate is refined without acid treatment; it is dried and mixed with 7 per cent each of the following fluxes: Borax glass, soda and sand.

Lead

Lead Smelting at El Paso.—A paper by H. F. Easter, assistant superintendent of the El Paso Smelting Works, El Paso, Tex., was presented at the San Francisco meeting of the American Institute of Mining Engineers, describing the plant and practice in the lead-smelting department. Lead-ore supply in recent years has been precarious, with a general tendency toward excess of silica and shortage of iron. To supply the latter a considerable amount of roasted leady copper matte from Chihuahua and converter matte from El Paso have been used. These materials, together with complex lead-copper ores from Arizona, have introduced an unusual amount of copper into the plant and have had an important bearing on the smelting practice.

Unloading is done by contract at rates based on the character of the car and the distance to which the ore must be wheeled. When the initial sampling is done by hand the rates include the cutting of the sample and wheeling it to the sample storage platform. An extra allowance is made for spreading the ore in the bin itself, as this must be done carefully by hand because of the different character of the numerous small lots which are bedded together. Hand sampling is done by taking every tenth shovel of the fines and setting aside the coarse lumps, from 6 in. up, for automatic sampling. The automatic plant contains the usual sampling equipment. The automatic sample is added to the hand-cut sample of fines, and the combined sample is then put through a smaller automatic sampling equipment. A sample from one car amounts to from 400 to 500 lb. It is circled, coned and quartered by hand until reduced to proper size for the bucking room. In the case of high-grade ore the whole lot is sampled automatically. Concentrates are shovel-sampled.

All ores requiring roasting are bedded. In general the best results are obtained when the mixture contains 20 per cent silicious sulphides with leady copper matte. Three Godfrey 30-ton roasting furnaces are used for the preliminary roast. Two are oil-fired and consume 0.22 bbl. of oil per ton roasted; the coil-fired furnace consumes 0.11 ton of coal per ton roasted, all of which, however, is not chargeable to roasting, as some half-burned material is drawn off for the Huntington-Heberlein pots. The pots handle two charges of 6 to 7 tons in twenty-four hours. Air pressure for the pots is 10 oz. The fine material in the sintered product amounts to from 5 to 10 per cent of the charge, and is added to the next charge. Sulphur in the final product averages about 5 per cent.

The hearth area of the blast furnaces at the tuyeres is 46 in. by 162 in. The average capacity is about 180 tons of charge per furnace day, although with a coarse charge it has frequently been better than 200 tons. Production of flue dust averages from 1½ to 2 per cent of the charge smelted. The flue system is 800 ft. long, of which the first 375 ft. is provided with hoppers that collect the greatest part of the dust. These hoppers are discharged into tram cars. The flue dust is briquetted with 10 per cent burned lime, and the briquets are allowed to dry for from three to six weeks.

The author devoted considerable attention to the difficulties experienced at El Paso in settling and separating leady copper matte from the slag, as this problem has been most vexing at the El Paso plant. Originally this operation was accomplished in a Rhodes separator, or small reverberatory furnace. This was satisfactory in the days of large lead tonnage, but has proved unsatisfactory with the present small tonnage of lead ores. These furnaces are now permanently abandoned. Experiments with small settlers in front of the furnaces were not satisfactory, as they tended to fill with zinc mush that seriously interfered with settling of matte. This condition was finally remedied by changing the charge so as to use less of the Huntington-Heberlein roast, and since that time similar troubles have been overcome by changes in the furnace and roaster charges.

The latest arrangement of settling devices is to have a rectangular box in front of and at an angle of 45 deg. with each furnace, and a large, oil-fired settler to serve each two furnaces. The furnace is connected with the rectangular box and the box with the settler by short water-coil spouts. The boxes are lined with magnesite brick all around. The settler measures 10 ft. by 20 ft. and is supported on rails running crosswise. Air spaces are provided beneath the bottom pan to keep seeping lead from progressing downward into the foundation. The sides and ends are lined with magnesite brick. A matte tap is provided on each side close to the front and a single lead tap in the middle at the rear end. Every effort is made to prevent lead getting into the settler, as experience with the Rhodes settler had shown the inadvisability of keeping a bath of molten lead in contact with matte. The settler requires about 7 bbl. of oil per day.

The Salida Smelter.—A description of the plant and lead-smelting practice at the plant of the Ohio & Colorado S. & R. Company, at Salida, Col., by F. D. Weeks, was presented at the San Francisco meeting of the American Institute of Mining Engineers. Some of the most interesting points in the paper are those relating to errors in construction and early operation. This smelter was one of the first to make a commercial installation of the Dwight-Lloyd sinter-roasting process, a description of which appeared in this journal, February, 1912. One of the results of the use of this process was to increase the capacity of a 48-in. by 180-in. blast furnace from 180 to 250 tons per day. Speaking of some of the peculiarities of construction of the original plant, the author says:

> Originally, a brick wall, with a narrow door in front of each blast furnace, was constructed. How the work was to be done behind this wall is not known, but it shows that the designer did not know how to do the work.
>
> The water jackets were held in place by a 12-in. I-beam running the length of the furnace, thus effectually preventing any one from examining a tuyere or jacket.
>
> The shaft walls on the feed floor were so thick that the feeders were shoving ore into one end of a tunnel, and, since the opening was not as wide as the shaft, the ends of the furnace could not be fed except by throwing the charge around a corner which, of course, was not done.
>
> The proposal to concentrate matte carrying 20 per cent lead and 5 per cent copper, in a copper-matting furnace was intended to do away with the necessity of roasting equipment.
>
> The largest Corliss engine on the plant was the exhibition engine at one of our world's fairs held some years ago. When repairs were needed, it was discovered that this was the only engine of the kind ever built, and the drawings of it were lost; so each repair part called for an accurate drawing.
>
> In the track plan of the works, all the ore, coke, and limestone had to be unloaded from one track. This track also held the cars which were to be unloaded at the oxide crusher as well as at the sulphide mill. The problem of dispersing some of this congestion was not simple. It was solved by building two trestles in place of one; by having the limestone brought in dump cars so that unloading took little

time; and by building an oxide crushing and screening plant on new tracks.

Referring again to the Dwight-Lloyd sintering plant, an important improvement has been made by placing an adjustable rail by the side of the pallets so that the weight of the pallets and their charge is carried on rollers and no dragged across the top of the wind box.

Recent Chemical and Metallurgical Patents

Electrolytic Processes

Caustic Soda and Chlorine.—An electrolytic cell of concrete for the production of caustic soda and chlorine is patented by Messrs. EDWARD A. ALLEN and HERBERT I. ALLEN of Maine (assigned to the Electron Chemical Company, Portland, Me.). Fig. 1 shows a perspective view of the cell and Fig. 2 a cross section. The cell consists of a main body containing the anodes 50, held by carbon rods 31, supported at the top of the cell. These carbon rods pass through the elliptical openings 17, which are made that shape to allow for the upward passage of the chlorine gas. The main body of the cell which comprises the anode chamber is open at its opposite ends, and against these open ends are placed the cathodes 20, held in place by clamps. The trough 15 is provided for catching the caustic soda solution which trickles down the cathodes. It may be drawn off through opening 16. The opening 30 is provided for introducing the brine solution. The cell may be made in two parts, one part consisting of the bottom and end pieces 11, and the other part the top piece with the anode openings, provided with a sliding connection. As it is only the cell which is patented the manner of operating or material of which the anodes and cathodes are made is not stated. (1,148,274, July 27, 1915.)

Caustic Soda and Chlorine.—A diaphragm cell for caustic soda and chlorine production is patented by Mr. HARRY R. NELSON of Elizabeth, N. J. This cell is shown in Fig. 3 in which 1 represents the outer casing which serves as a support at 3 and 4, for the cell proper 2. The cell proper contains the diaphragm 5 of asbestos and the cathode 6 and anodes 7, below the dome chlorine chamber 9 of slate or other non-conducting material. The cathode 6 of perforated iron is pressed against the outside surface of the diaphragm. The outer casing is made gas-tight at the angle 13, and the inlet pipes 14, 15 are provided for supplying steam, which is controlled by the valves 16. Outside of the cathode are screens 17 and 18 held in place by the strips 20. The removable strips 21 are provided for catching any solid matter. In the operation of the cell sodium chloride solution is supplied from the top through a pipe between the cathodes, the evolved chlorine is collected in chamber 9, and discharged through opening 28. "The cation sodium encounters the steam supplied through the inlet pipes 14, 15 and forms caustic liquor of high concentration, with the evolution of hydrogen." The pressure of the steam at the inlet pipes 14, 15 is such as to maintain a "faint" cloud within the casing 1. The evolved hydrogen passes upward along the outer side of the cathode 6 and is discharged. The caustic liquor formed trickles down the outside of the cathode 6, and is caught in the tilting pan 22, which empties into the larger pan 23, provided with the discharge 25. Dry steam is preferably used and for this purpose the trap 31 is provided. The use of steam is claimed to give greater efficiency of production. (1,149,210 and 1,149,211, Aug. 10, 1915.)

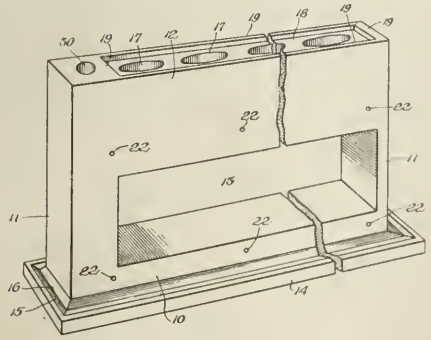


FIG. 1—ELECTROLYTIC CELL FOR CAUSTIC SODA AND CHLORINE

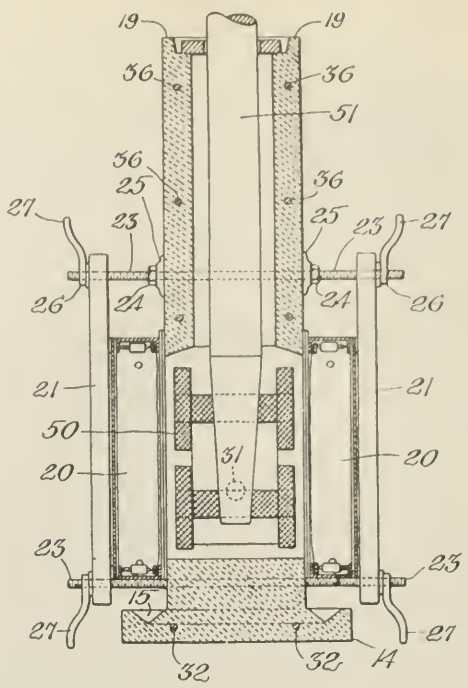


FIG. 2—CROSS-SECTION OF ELECTROLYTIC CELL FOR CAUSTIC SODA AND CHLORINE

Caustic Soda and Chlorine.—An electrolytic cell of the bell type ("gravity cell") is patented by Mr. HENRY CHARLES JENKINS of London, England. In this cell

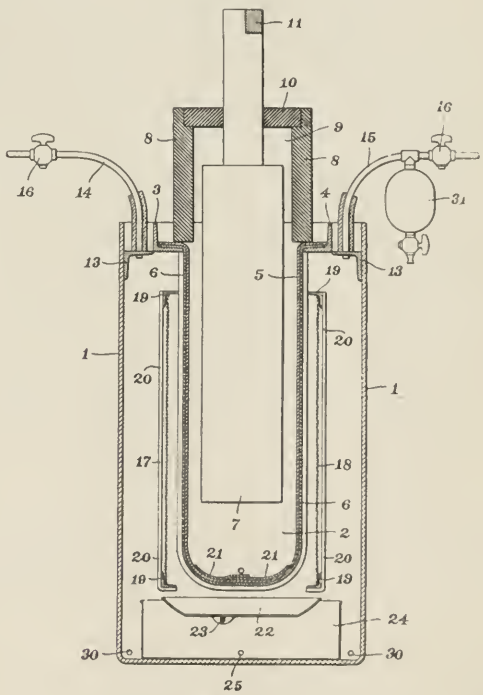


FIG. 3—DIAPHRAGM CELL FOR CAUSTIC SODA AND CHLORINE

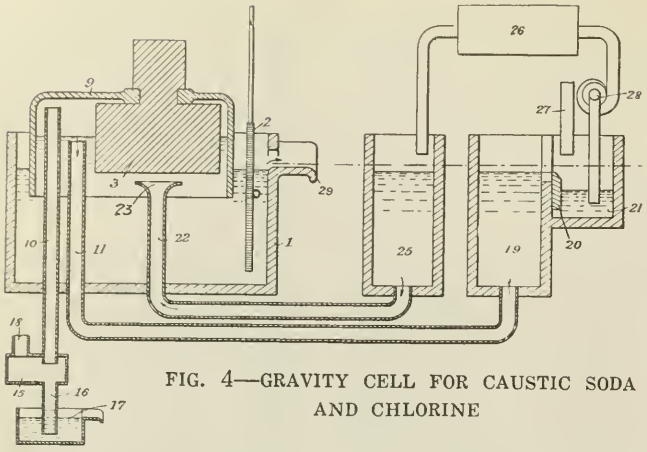


FIG. 4—GRAVITY CELL FOR CAUSTIC SODA AND CHLORINE

which is shown in Fig. 4, a bell 9 dips down into the casing 1, the bell being open at the bottom. The anode 3 is fastened to the bell by an air-tight connection. The cathode 2 is arranged as shown and may be made in any suitable manner so as to provide for the removal of gases formed thereon. For introducing fresh brine solution pipe 22 is provided, connected to tank 25, the fresh solution being delivered directly beneath the anode. For conducting solution away and thus circulating the electrolyte, pipe 11 is provided, connected to tank 19 which has an adjustable weir 20. In this manner the liquid in the cell may be kept at any desired height. At 28 is indicated a pump for circulating the electrolyte and at 26 a heating apparatus. Fresh brine solution may be introduced in 21 by pipe 27. For conducting away the chlorine gas formed in the bell, pipe 10 is provided, connected to a device for separating any liquid from the gas at 16. The caustic soda solution overflows at 29. (1,150,370, Aug. 17, 1915.)

Improvements in Electrolytic Copper Refining.—A patent for a new method of handling the solutions in electrolytic refining has been granted to Messrs. Francis R. Pyne and Henry M. Green and assigned to the U. S. Metals Refining Company of Chrome, N. J. In the usual electrolytic copper refining process, the solution is circulated by introducing and withdrawing the liquid to provide an even distribution. The solution withdrawn from the tank is then treated in a second tank or series of tanks to recover more of the copper, before treating the solution further to recover secondary constituents known as impurities. In this second treatment it is necessary to use insoluble anodes and consequently a higher voltage and more energy. The deposit in the second electrolysis is usually inferior to the first deposit. The solution after second treatment is then used to recover the secondary constituents.

The present patent proposes to utilize the fact that solutions stratify when the current is passing, and to allow the solution to stratify, withdrawing same from different levels. In this manner the solutions withdrawn may be regulated so that the primary solution is sufficiently strong in copper to be led into a second tank, where it is treated same as before, while the secondary solution is so poor in copper that it may be directly treated for recovery of the secondary constituents. This effects a saving in power owing to the elimination of the insoluble anode treatment. In Fig. 5, a tank is shown with entry for solution at *B*. It was found that the copper solution was purest on the lower level at *C*, and the concentration of impurities greatest at the upper level *D*. *E* is a pipe for withdrawing primary solution for second tank and *F* and *F'* pipes for withdrawing solution rich in impurities. A certain amount of circulation is necessary but is not usually as rapid as in the old process. The process produces a greater output of merchantable product than heretofore by enabling the series of tanks to operate under conditions similar to the first series, effecting a saving in electrical energy. (1,148,798, Aug. 3, 1915.)

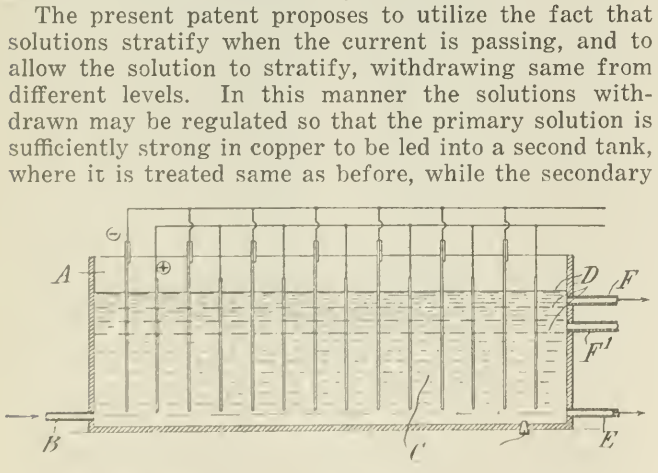


FIG. 5—ELECTROLYTIC COPPER REFINING TANK

Regenerating Electrolyte in Copper Refining.—A process for purifying the sulphuric acid electrolyte used in copper refining and for recovering arsenic contained in it is patented by Oliver Curtis Martin and Frederick Jaeger of Perth Amboy, N. J. The electrolyte is first nearly freed from copper by electrolyzing with an insoluble anode or by evaporation and crystallization or both. It is preferred to remove as much copper as possible with the insoluble anode. After removing the copper one method is to evaporate the solution until it contains 74 per cent sulphuric acid, and then boil with charcoal by which some of the sulphuric acid is reduced to sulphurous. The latter attacks the arsenic acid reducing it to arsenious. Carbonic acid is liberated. The solution is then diluted to 38 per cent sulphuric acid and allowed to cool, causing the arsenious acid to be precipitated. This method is preferably used when the copper is removed by evaporation.

Another method which is preferably used where the copper is removed by electrolysis is to subject the solution to sulphurous acid gas and concentrate or dilute to 38 per cent, when upon cooling the arsenious anhydride separates out, which may be purified by sublimation giving a marketable product.—(1,148,522, Aug. 3, 1915.)

Method of Cleaning Articles.—A process for removing tarnish and stains from silverware and other metals is patented by Mr. Elbert L. Couch of Hartford, Conn. (assigned to the Couch-Dean Corporation, of the same place). In this process the articles to be cleaned are placed on a traveling belt having a surface of tin or aluminium and sprayed by suitable means with an electrolyte. In this manner a short-circuited couple is formed and the oxide tarnishes are reduced to metal. The apparatus in which the cleaning is carried out is essentially the same as that in patent 1,068,568, July 29, 1913, granted to Mr. Couch and the electrolyte used, termed "silverease" was also patented by him in patent 674,254 of May 14, 1901. (1,150,101, Aug. 17, 1915.)

Electric Furnaces

Manufacturing Articles from Silica, Magnesia, Etc.—In a process patented by Prescott M. Hulbert of Detroit, Mich., finely divided refractory material such as silica is compressed in a mold of graphite and the mold is heated in an electric arc furnace to a temperature near the fusing point of the material. This causes the particles to integrate and form a solid compact form, the shape of the mold. No binder is necessary and the integration may be carried to any degree according to the heat employed. An artificial graphite cylinder may be placed in the center and extending nearly through the mold, and connected to electric terminals. The refractory material is inside and surrounding this cylinder and thus a means is provided for further heating of the material. A certain amount of shrinkage will occur,

which will, however, be lessened by using finely ground material.—(1,155,358, Oct. 5, 1915.)

Manufacture of Pure Carbon.—Pure carbon can be made from tar oils or other hydrocarbons for use in the manufacture of electrodes or other electrical conductors according to a patent of HENRI HENNEBUTTE of Paris, France (assigned to Société Anonyme des Combustibles Industriels of Paris, France). In this process the hydrocarbon to be used is left standing, or is filtered to remove any mineral dust. It is then passed either in a liquid or gaseous state into a still from the top. A steam coil in the still heats the oil and air is forced in to dehydrogenate the mass. A solvent such as benzine is then admitted and the dissolved portion is led away at the bottom through a pipe to another still. The insoluble oxidized mass of material which has been dehydrogenated is then heated further until it is thoroughly carbonized. The material in the second still may be distilled and the residue treated in the first still. The temperatures used in all cases depend on the raw materials used.—(1,155,419, Oct. 5, 1915.)

Reduction of Zinc Oxide in an Electric Furnace.—A process for the production of pure zinc from oxide or blue powder is patented by FRANK WILLIAM HIGHFIELD of Caversham, England. The oxide is fed into a furnace from the top, onto a bed of coke which forms the resistor for the furnace. The coke is heated to redness by the current and forms an atmosphere of carbon monoxide which together with the glowing carbon reduces the oxide to metal. The metal is condensed and trickles down through the coke and is led through a cooling chamber in which oxygen is excluded and is then discharged. The temperature should be about 1050 deg. C. A cross-section of the furnace is shown in Fig. 6. The oxide is fed in at *C* by the conical feed and passes through the tube *D* which is of fireclay so as to be porous to carbon monoxide. The bed of coke rests on bars *F* and is in contact with the electrodes *E*. The tube *D* is intended to provide a condensing surface. The condensed metal is caught at *A*, and led through the cooling chamber. The advantages of this method are claimed to be that it gives a large condensation surface which is necessary on account of the low vapor pressure of the metal and, by starting with the oxide instead of treating zinc ores direct for the recovering of pure zinc many difficulties are overcome.—(1,153,786, Sept. 14, 1915.)

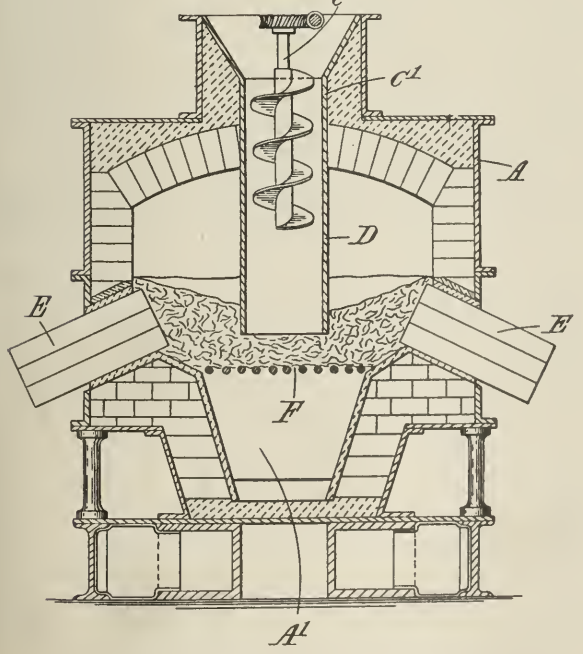


FIG. 6—ELECTRIC ZINC FURNACE

Chemical Engineering

Apparatus for Distillation of Peat.—In order to extract valuable ingredients from peat and produce coke a distillation apparatus has been patented by ELLIS BARTHOLOMEW of Toledo, Ohio (assigned to the National Peat Refining Company, Cleveland, Ohio). In this apparatus peat is fed from a closed bin 1 by a screw conveyor 4 to a cylinder called a separator shown in Fig. 7 at 10. The bottom of this separator is made hopper-shape and directs the peat on to a grate of electrically heated resistance bars 23. The heat of the bars drives off the gases from the heat converting it into coke. The gases pass up and out through openings 39 and the coke is shaken through the grate by suitable means, dropping into another conveyor, whence it is led to a bin. The separator and peat bin are kept full of the gas from the peat, so as to exclude air. For this purpose a reservoir of the gas is connected to valve 41. The gases which pass out through 39 are passed through suitable condensers where the lighter and heavier liquids are obtained.—(1,156,387, Oct. 12, 1915.)

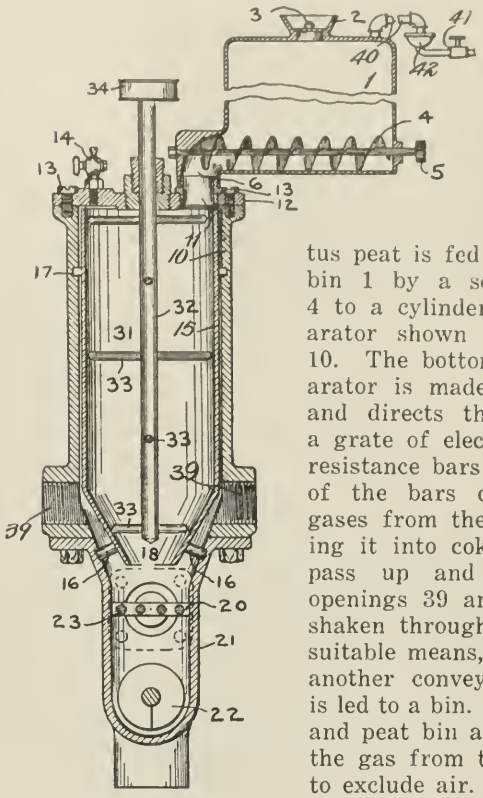


FIG. 7—DISTILLATION OF PEAT

Iron and Steel

Manufacture of Steel.—In adding the necessary additional elements to refined molten iron for making steel it is claimed to be advantageous if the additions are first dissolved in a separate subsidiary bath of refined iron and then this separate bath added to the main bath of refined iron in the casting ladle where they become mixed together. A patent which comprises these features has been granted to JEGOR ISRAEL BRONN of Rombach, Germany (one-half assigned to Rombacher Hüttenwerke, Rombach, Germany). The dissolving furnace is charged with molten refined iron which is usually available in steel works and then the desired additions such as carbon, manganese, silicon, titanium, etc., are made either in the pure state or as ferro-alloys. This gives an exact method of making additions, whereas in making additions directly to the main bath, losses of carbon and other constituents occur through the slag and gasification. It also provides a means for making carbon steels almost free from manganese or manganese steels poor in carbon, which was more difficult by the old method because in spiegeleisen or ferro-manganese which were generally used the proportion between the contained manganese and carbon is almost fixed. Another advantage occurs when it is desired to add only very small amounts of a metal such as titanium or vanadium. In the old method the small amounts of added metal might not become thoroughly diffused

throughout the bath, while in this process the chance that they will is much greater since the original bath to which they are added is so much smaller.—(1,156,051, Oct. 12, 1915.)

Lead

Treatment of Carbonaceous Fuel for Metal Reduction Furnaces.—In a process patented by William D. Kilbourn of Tooele, Utah, it is proposed to form a coating on the coke or other combustible material, for the purpose of preventing combustion in the zones of the furnace where it is undesirable. In shaft furnaces, by selecting a coating which melts at the right temperature, combustion of the fuel can obviously be made to take place at any point. In this manner hot-tops, wall accretions in the upper part of the furnace, and consequent heat losses at the top may be prevented. For lead blast-furnace practice it has been found that a good coating may be made from a mixture of lead sulphate, lead oxide and a varying percentage of impurities, the mixture to contain about 60 per cent lead. This makes a good pigment which sticks to the coke and protects it from the fire until it reaches the lower part of the furnace. Thus fuel of a size adapted to be charged into a blast furnace may be treated without briquetting.—(1,148,782, Aug. 3, 1915.)

Conveyor Belt Calculating Chart

At the San Francisco meeting of the American Institute of Mining Engineers, September, 1915, Messrs. J. D. Mooney and D. L. Darnell of the B. F. Goodrich Company, Akron, Ohio, presented the following chart and discussion.

The chart has been drawn for the convenience of engineers as a means of quickly determining the correct number of plies of conveyor belts operating under specific conditions.

The calculations are based on the average safe strength (factor of safety, 15) of the various standard rubber conveyor belts.

The calculations assume maximum loading conditions; that is, the belt is considered as carrying the greatest load that it will handle without spillage at ordinary belt speeds. This not only produces the most economical operating conditions, but also the maximum tension in the belt.

The chart is a graphical representation of the formula:

$$p = kgW(L + 10H)$$

Where p = the correct number of plies.
k = a constant, depending on the type of drive.
g = the weight in pounds per cubic foot of material handled.
W = the width of the belt in inches.
L = the length of the belt in feet (approximately twice the center distance).
H = the difference in elevation between the head and tail pulleys, in feet.

For a simple drive, with a bare pulley,

$$k = \frac{1}{250{,}000}$$

For a simple drive, with a rubber-lagged pulley,

$$k = \frac{1}{300{,}000}$$

For a tandem driver, with bare pulleys,

$$k = \frac{1}{375{,}000}$$

For a tandem drive, with rubber-lagged pulleys,

$$k = \frac{1}{455{,}000}$$

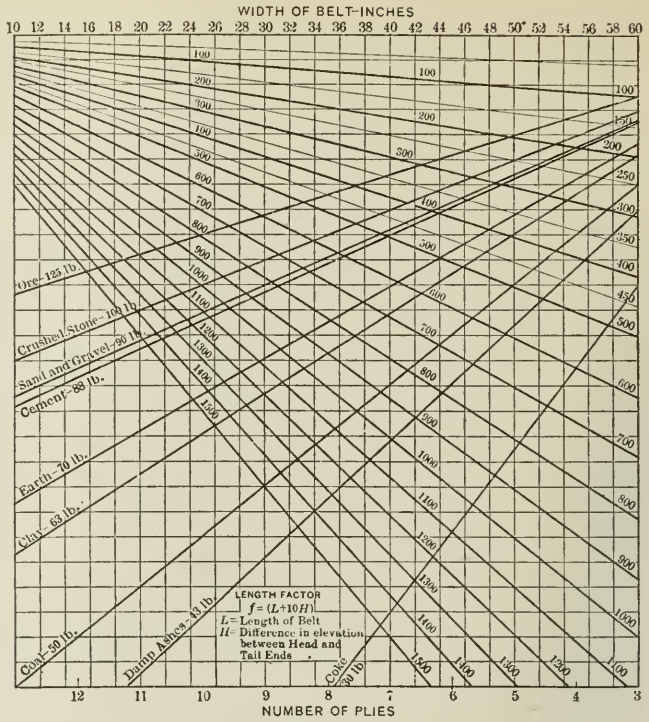

WIDTH OF BELT-INCHES
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
Ore-125 lb.
Crushed Stone-100 lb.
Sand and Gravel-90 lb.
Cement-88 lb.
Earth-70 lb.
Clay-63 lb.
Coal-50 lb.
Damp Ashes-43 lb.
Coke-30 lb.
LENGTH FACTOR
f = (L+10H)
L= Length of Belt
H= Difference in elevation between Head and Tail Ends
12 11 10 9 8 7 6 5 4 3
NUMBER OF PLIES

FIG. 1—CONVEYOR BELT CALCULATING CHART

The chart is drawn for a simple drive, with a bare pulley $\left(k = \frac{1}{250{,}000}\right)$; therefore, the number of plies obtained from the chart should be multiplied by the factor 0.83 or 5/6 for simple, lagged drive; the factor 0.67 or 2/3 for tandem, bare, and the factor 0.55 or 11/20, for tandem, lagged.

The formula $p = kgW(L + 10H)$ has been developed mathematically from the following formulas, which have been found to work very satisfactorily in average good practice:

$$U = \frac{0.08W^2Sg}{5000}$$

$$HP = \left(\frac{0.02l}{100} + \frac{0.01H}{10}\right)U$$

$$T = \frac{C \times HP \times 100}{S}$$

$$p = \frac{T}{24W}$$

Where U = Capacity in tons per hour,
W = Width of belt in inches,
S = Belt speed in feet per minute,
g = Weight per cubic foot of material handled,
HP = Horsepower developed in driving conveyor belt,
l = Length of the conveyor, in feet (approximately $\frac{1}{2}L$),
H = The difference in elevation between the head and tail pulleys, in feet,
T = The total tension in the belt, in pounds,
p = Correct number of plies,
C = The constant of the drive.

For a simple drive, bare pulley, $C = 600$
For a simple drive, rubber-lagged pulley, $C = 500$
For a tandem drive, bare pulleys, $C = 400$
For a tandem drive, rubber-lagged pulleys, $C = 330$

The length factor, $f = (L + 10H)$, represented on the chart by the lines 500, 600, 700, etc., is a developed factor equal to the sum of the length of the belt and ten times the difference in elevation between the head and tail pulleys.

To find the correct number of plies for a conveyor belt, knowing the width, the length, the difference in elevation between the head and tail ends, and the kind of material to be handled:

Start from the width given at the top of the chart and move down until this line intersects the line corresponding to the proper length factor; then move either right or left until the line corresponding to the given material is met; then move down again to the scale of plies, where the next largest figure will give the correct number of plies.

For example: To find the correct number of plies for a conveyor belt 36 in. wide and 300 ft. long, with 20 ft. difference in elevation, handling sand and gravel:

Follow the line from the 36-in. width downward until it intersects the 500 length factor line; then follow to the right until the sand and gravel line is intersected; then down to the ply scale, where the ply will be found to be 7.

New Portable Direct-Current and Alternating-Current Electrodynamometer Instruments

Problems hitherto considered impossible of solution have been solved in the design of the new electrodynamometer instruments of the Weston Electrical Instrument Co. of Newark, N. J. They are the latest development of instruments of this type and embody characteristics never before attained. There are four instruments of this type.

The portable electrodynamometer **wattmeter**, model 310, is adapted to measurements of precision on alternating-current or direct-current circuits and is guaranteed to an accuracy of ¼ to 1 per cent of full scale value, either on direct or single-phase alternating-current circuits of any frequency to 133 cycles per second and any wave form. It can be used on circuits of any commercial frequency, even as high as 500 cycles per second, with very slight error due to phase displacement. Double ranges are provided for both current and voltage circuits. All current ranges can be used for 100 per cent overload indefinitely without introducing error.

The movable system has an extremely low moment of inertia and is very effectively damped. Indications are independent of room temperature and of the heating effect of current passing through the windings, and the instruments are shielded from external magnetic influences.

The scales, which are 5¼ in. long, are uniform throughout their entire length, a characteristic of great importance. Each scale is hand-calibrated and is provided with a mirror over which the knife-edge pointer travels, and the pointers are equipped with a simple zero setting device.

Special model 310 wattmeters can be furnished for very low power factors, for instance, for the determination of the core losses in transformers, giving full-scale deflection for 20 per cent power factor; that is, the scale value in watts is 20 per cent of the volt-amperes applied. Temperature errors are very small and can be corrected by reference to the certificate that accompanies all Weston instruments. Scales are uniform and the instruments have otherwise the same general characteristics as the regular model.

While model 310 is a direct-current or single-phase wattmeter, model 329 is a polyphase wattmeter; otherwise the above remarks agree likewise to model 329.

FIG. 1—OUTSIDE VIEW OF ELECTRODYNAMOMETER VOLTMETER

Model 341 is a direct-current or alternating-current portable electrodynamometer **voltmeter** and model 370 is a direct-current or alternating-current portable electrodynamometer **ammeter.** Their accuracy is the same as that of the wattmeter.

The scales of the voltmeter and ammeter are 5¼ in. long. Owing to the principle of operation these instruments cannot be made with scales that are uniform throughout their entire length, but the upper four-fifths portion of the scale is remarkably legible and uniform.

Undoubtedly the perfection of this new kind of instrument marks a distinct advance in the science and practice of electrical measurements.

New Riffling for Concentrating Tables

Progress in the art of concentration or ore-dressing has developed a number of new methods of riffling tables for special purposes. Several new types of riffling for Wilfley tables have been brought out by the Mine & Smelter Supply Company, Denver, Col., one of these; known as the No. 10 deck, being shown in two views in Figs. 1 and 2. The particular deck shown is installed in the metallurgical laboratory of the Colorado School of Mines, where it has been used successfully in making close separations with greater efficiency than could be obtained on the ordinary Wilfley deck.

In the No. 10 type of deck, three riffles extend parallel with, and the full length of, the lower edge of the table. Above these, the riffles which perform the main work of stratification are laid diagonally from the head-motion end toward the feed and wash-water boxes. These riffles terminate in a diagonal line, and every alternate one is extended a few inches at a smaller inclination toward the discharge end of the deck. These extensions also terminate in a diagonal line, except

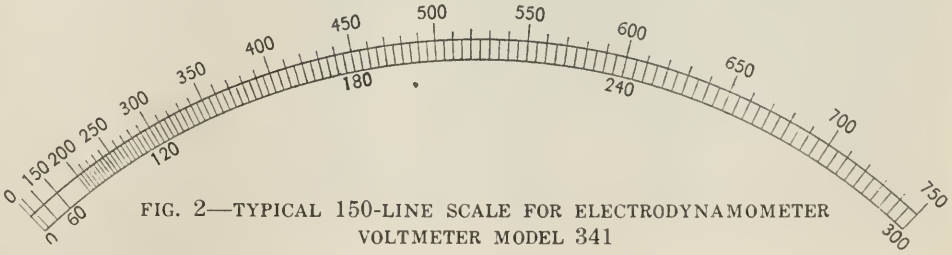


FIG. 2—TYPICAL 150-LINE SCALE FOR ELECTRODYNAMOMETER VOLTMETER MODEL 341

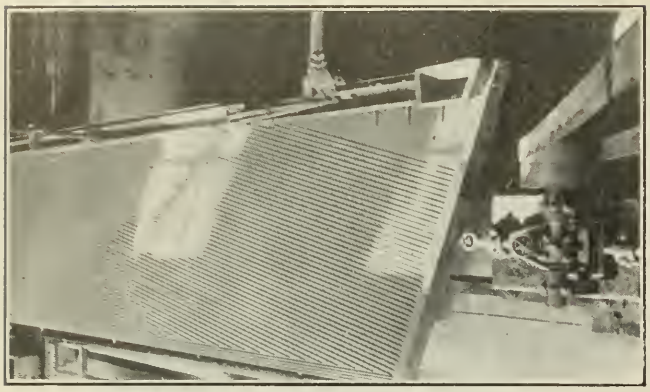


FIG. 1—NEW ARRANGEMENT OF RIFFLES

those near the lower side of the table, which extend to the discharge end. A feature essential to the proper distribution and stratification of the pulp is the three wooden cleats shown near the feed-box.

The improvement shown by the new deck over previous models is primarily an enormous increase in capacity, although greater efficiency has been found in separating minerals of nearly the same specific gravity. Under suitable conditions, where only a one-mineral separation is required, this table will handle up to five times as much unclassified-sand feed as earlier models. A relative increase in tonnage is obtainable with a classified feed for two-mineral separation. This increase in capacity is not gained at the sacrifice of quality in work done. The table is not a "rougher" in the usual sense of that term, for it delivers a finished product, combining the capacity of a roughing table with the efficiency of a finishing table.

A novelty in roughing tables is in use at Silverton, Col., where tables 12 ft. wide and 45 ft. long are handling a tremendous tonnage of old tailings that are being retreated. The feed is classified into coarse and fine grades, and both are fed to the same table—the coarse at the usual feed box and the fine near the discharge end.

Another development in rough concentration is the use of tables for the work formerly done by jigs in coal washing. The deck of a coal-washing table is 7 ft. by 16 ft., riffled horizontally over its entire surface. The capacity is from four to six tons per hour of feed broken to pass a ¼-in. ring. It is claimed that the table does more efficient work than the jig.

For concentration of classified-sand pulp on the ordinary Wilfley deck, some modifications of riffling have been introduced with good effect. With an unclassified feed every third or fourth riffle can be made higher than the others, producing a pond or lake in which stratification and separation can be made more effective. With this type of riffling the vortex usually formed when the pulp flows over each riffle is confined only to the high riffles, while the intervening area is undisturbed by these currents.

FIG. 2—ANOTHER VIEW OF NEW ARRANGEMENT OF RIFFLES

Personal

Mr. Charles W. Baker, formerly New York manager of sales of the Carnegie Steel Company, has been elected a director of the American Zinc, Lead & Smelting Co.

Mr. J. L. W. Birkinbine has been selected as consulting engineer of the Bureau of Mines and will prepare a monograph on the manufacture of iron and steel in this country.

Mr. G. Montague Butler is now Dean of the College of Mines and Engineering of the University of Arizona, Tucson, having resigned his position as professor of geology in the School of Mines, Corvallis, Oregon.

Mr. L. Collins of the Metal Coating Co. of America will lecture on November 18 before the Buffalo branch of the American Society of Mechanical Engineers on their process of coating metals (Schoop process) and on the following two days will demonstrate their process at the plant of the J. P. Devine Co. at Buffalo.

Mr. J. D. Connor, metallurgist of the South Australian Government, has recently arrived in this country to investigate the leaching of copper ores.

Mr. J. V. N. Dorr and **Mr. George E. Collins** will represent the Colorado Scientific Society in Washington on December 16 at a convention to be held under the auspices of the Mining and Metallurgical Society of America for the purpose of presenting to Congress the necessity of changes in the mining laws. Mr. Dorr is at present in Denver but expects to return to New York City about Thanksgiving time.

Dr. Francis C. Frary, formerly assistant professor of chemistry in the University of Minnesota, is now research chemist for the Oldbury Electrochemical Co., Niagara Falls, N. Y.

Mr. Edward Hamilton, formerly assistant superintendent of the Duquesne Works of the Carnegie Steel Co., is now general superintendent, succeeding **Mr. Homer D. Williams,** the recently elected president.

Mr. Henry D. Hibbard of Plainfield, N. J., has gone to Australia on a business trip.

Mr. H. O. Howard of San Francisco is in Nevada making an investigation of the districts around Lovelock.

Mr. Wasata Kondo and **Mr. M. Yamashita** of Japan have recently come to this country to make a study of metallurgical practice.

Mr. James F. McCarthy has been appointed manager of the National Copper Mining Co., Mullan, Idaho.

Mr. Edward McFarlan has been placed in charge of the New York office of the Metals Coating Co. of America, recently opened at 30 Church Street. This company owns the patents for the Schoop spray process.

Mr. F. E. Marcy of the Mine & Smelter Supply Co., Denver, Colo., has resigned to go into business of his own.

Mr. J. J. Rockwell has rejoined the staff of the McGraw Publishing Company, publisher of "Metallurgical and Chemical Engineering," "Electrical World," "Electric Railway Journal," and "Engineering Record," as advertising counselor.

Mr. Richard K. Meade of Baltimore, Md., has been retained by the D. M. Bare Paper Company of Roaring Springs, Pa., to prepare plans and to superintend the construction of a lime recovery plant for converting the lime waste or sludge now discarded into lime of the highest quality. The kiln will be a giant revolv-

ing cylinder 6 ft. in diameter and 100 ft. long, and the lime as it falls red hot from this kiln will be automatically cooled and conveyed to the lime house. Novel features will be introduced in the heating of the kiln and all of the machinery will be motor-driven.

Mr. C. A. Menk of the Homestead Works of the Carnegie Steel Co., was elected second vice-president of the Association of Iron and Steel Electrical Engineers at its recent Detroit convention.

Mr. Thos. M. Skinner, Jr., has completed his work pertaining to the handling of the alkali waters of Owens Lake, Cal., and has returned to Denver, Colo.

Mr. Acheson Smith, general manager of the International Acheson Graphite Company, has been nominated as one of the commissioners for the proposed commission government of Niagara Falls, N. Y. Mr. Smith has the best wishes of his many friends in the electrochemical and electrometallurgical industries of this country for his election on Nov. 2.

Mr. C. W. Whitley of the American Smelting & Refining Co., was elected chairman of the Utah Section of the A. I. M. E. at their first annual meeting on Oct. 4, in Salt Lake City.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(*Continued*)

151,892, June 9, 1874, Henry Lovejoy, Henry W. Lovejoy and James H. Ferguson of Brooklyn and Michael J. Creegan of New York, N. Y.

Relates to an apparatus for electroplating, consisting of a hanger or hook for suspending articles to be plated, such as molds for electrotypes, etc. The hanger consists of a metallic bar, having a ring at the top for handling, and a hook by which the bar is suspended from the conducting rod. The bottom of the bar is divided so as to form two arms extending laterally a short distance on both sides, and turning toward the front, their ends forming bearers for the mold. Between the arms is secured insulating material, which supports a hook by which the mold is suspended. (This patent was reissued under No. 8726, dated May 27, 1879.)

158,972, Jan. 19, 1875, Henry E. Osborn of Wallingford, Conn.

Relates to racks for electroplating, and consists in a thin, flat bar, suspended horizontally by hooks hanging from a conductor above the bath, the flat bar being slotted longitudinally, the slot being notched on each side by rounded saw-tooth notches, the notches on one side being opposite those on the other. Spoon handlers, and the like, are inserted flat-wire in the slot, and then turned at right angles and placed in the notches, the spoon being thereby suspended and electrically connected for plating. They may be arranged to support a dozen or more spoons at one time.

169,878, Nov. 9, 1875, Stephen W. Wood of Cornwall, N. Y.

Relates to the manufacture of metal tubing by electrodeposition, and the removal of the tubing from the mandrel upon which it was deposited. A metallic mandrel having a polished dense surface is used as the cathode, and metal deposited thereon to a desired thickness. The coated mandrel is then subjected to a rolling, burnishing, or drawing process to loosen the deposit, the patent illustrating a system of rollers which are said to answer the purpose. The rolling action expands the deposited metal which thereby separates from the mandrel. After its removal the tube may be drawn to any suitable size.

192,112, June 19, 1877, William B. Closson of Boston, Mass.

Relates to the production of molds for the duplication of medals, etc., from an original. The medal desired to be reproduced is surrounded with two split frames of thin metal, having smooth surfaces which are pressed tightly together. Holes are previously made in one piece, and corresponding indentations in the other piece of metal registering with the holes. The combined metal sheets and medal are provided with wax masses on each side at one point to form sprue holes or openings for molten metal. The medal and the wax are covered with graphite, and the assembled form electroplated. After a sufficient deposit has been formed, it is removed, the edges around the metal sheets filed off and the two sheets of metal separated, each supporting one-half of the deposit, and the medal removed. The two parts of the mold may be readily assembled, the indentations registering with the holes. The sides may be reinforced by molten lead, plaster of paris, etc.

195,443, Sept. 25, 1877, William B. Closson of Boston, Mass.

Relates to a method of forming electroplated molds for casting articles of statuary, etc. The object to be duplicated is coated with wax, a portion is then uncovered, leaving perpendicular walls on the wax coating. The article and walls of the wax are then coated with graphite, and then electroplated. Then a second portion of the mold is uncovered, leaving perpendicular sides on the wax remaining, and using one wall of the prior deposit as a surface for a new wall. This is then coated with graphite and electroplated. The entire object to be reproduced is treated in this manner, care being taken that the several portions uncovered and on which deposits are made shall form readily removable mold sections. These several sections, when completed, are to be assembled to form a complete mold.

197,408, Nov. 20, 1877, Julius W. Rogers of West Meriden, Conn.

Relates to frames for holding articles to be electroplated. It consists of an expansible grid, adjustable so as to hold articles of different sizes, the grid consisting of a plurality of parallel rods below which are attached flat springs, a spring on one rod pressing against a spring on the next rod. Articles to be plated, such as screws and the like, are pressed between the springs, the head of the screw remaining exposed and may be immersed in the solution without immersing the springs. For large articles the frame is expanded, giving a wider space between the springs.

Reissue 8726, May 27, 1879, Henry Lovejoy, Henry W. Lovejoy and James H. Ferguson of Brooklyn and Michael J. Creegan of New York, N. Y.

This patent contains a more complete description of the hanger described in the original patent (No. 151,892).

218,473, Aug. 12, 1879. Robert Barrie of Chelsea, Mass.

Relates to making duplicates of statuary, etc., and consists in first making a mold, preferably sectional, by coating the object with wax, exposing a portion and leaving deep perpendicular sides on the wax edges, coating the wax and object with graphite, and electroplating, the perpendicular sides of the wax forming flanges for the sections of the mold. After the entire object has been treated in this manner the flanges are drilled for

the reception of bolts to aid in reassembling, and the several sections then removed from the object, and after reassembling, is dusted with graphite inside and electroplated with any metal of which the duplicate is desired. When completed, the mold sections are removed, and the article finished by buffing, etc., or otherwise.

224,478, Feb. 10, 1880, Julius W. Rogers of West Meriden, Conn.

Relates to frames for supporting articles to be electroplated, the frame consisting of a suitable holder such as a drilled metal ring or rectangle of any shape, with arms for suspending the same, the outer surfaces of the ring and arms being covered with a glazing of vitrified material such as glass, etc., which prevents the deposition of metal on the ring.

Book Reviews

The Mineral Industry. Its Statistics, Technology and Trade during 1914. Edited by **G. A. Roush**, M.S. Large octavo, XVIII + 998 pages. Price $10. New York: McGraw-Hill Book Company, Inc.

At the present time each successive volume of this annual has a more difficult task in living up to the reputation and standard of its predecessors. Yet the present editor seems equal to the task, and the present volume is the best which has appeared in recent years. Besides the contributions from the "old standbys," which need no further comment, we must record the addition of many familiar names to the list of contributors. Heading such a list is an introductory article by the director of the U. S. Geological Survey, Mr. George Otis Smith, which discusses the dislocation and readjustment of various mineral industries resulting from the present world war. Dr. David T. Day writes authoritatively on his specialty, petroleum and natural gas; Prof. James F. Kemp on platinum, Dr. F. G. Cottrell and Linn Bradley on the smoke problem, Clifford Richardson on asphalt, Kenneth Seaver on refractory materials, and so the list could be extended, including many prominent specialists in the mining, metallurgical, and chemical fields. It is a symphony of experts whose work it were presumptuous to criticise rashly, yet we must express regret that Professor Richards is unable to furnish anything more reliable than estimates (or perhaps they are "guesstimates") of the annual production of aluminium, and perhaps there are a few other discordant notes in the symphony. But criticism is really captious, since the strong points of the work so utterly outnumber its minor shortcomings. It deserves, as a whole, the heartiest recommendation to all who wish to keep abreast of the latest developments in the mining and metallurgical industries.

Abridged Scientific Publications from the Research Laboratory of the Eastman Kodak Company, 1913-1914. 76 pages, illustrated. Rochester, N. Y.: Eastman Kodak Company.

"Research work in any field is of many different grades, ranging from the investigation of the fundamental problems of a science to the working out of the purely practical problems in production. Research problems show a tendency to fall into three chief classes: (1) Problems of purely scientific interest; (2) problems in applied science, largely the determination of exact data and the working out of methods of testing, (3) engineering problems in the application of scientific data and laws and routine testing. Industrial research laboratories usually cover the first two classes of research in any given field, the third class is taken care of by individual departments of the works.

"The Research Laboratory of the Eastman Kodak Company is organized in accordance with these principles. Some work is being carried on along lines leading to results of no apparent practical importance whatever. On the other hand, practical problems of a very recondite nature are referred to it at times by the manufacturing department. But the great bulk of its work lies in the middle ground of the investigation of the properties of materials, including the determination of precise physical and chemical data, a large proportion of the investigation being initiated by the men within the laboratory.

"There are three chief departments of the laboratory: Chemistry, physics and photography, about equally balanced as regards number of men and space occupied. The chemical department contains subdivisions dealing chiefly with problems in inorganic, organic and colloid chemistry. The work of the physics department is chiefly along the lines of photometry, spectroscopy, lens optics, visual and photographic optics, colorimetry, and allied subjects. Photographic research covers photographic chemistry and the various photographic processes. Many problems are, of course, investigated by two or more departments in co-operation. Technical research, routine tests of product, the investigation of works troubles and the development of new works processes are fully provided for outside the Research Laboratory.

"The Laboratory was organized in 1912, and work was in full swing in the new building early in 1913. The more important scientific results of general interest that have been obtained have been published in various scientific journals. Some of these are not available to many who wish these results and hence an abstract journal is being published which shall contain all of the more important results of each paper. This number contains abstracts of all scientific papers published during 1913 and 1914."

There are twenty-two papers in number, namely: The Absorption of Light in Heterogeneous Media, by P. G. Nutting; The Physical Chemistry of Photographic Development, by C. E. K. Mees; The Sensitometry of Process Plates, by C. E. K. Mees; Calculation of Exposure, by C. E. K. Mees; The Triple Projection Process of Color Photography, by C. E. K. Mees; Brightness and Contrast in Optical Images, by P. G. Nutting; The Correction of Process Lenses for Light in the Extreme Violet, by P. G. Nutting; The Distribution of the Silver Grain in the Developed Image, by Orin Tugman; A New Standard Light Source, by L. A. Jones; Color Analyses of Two Component Mixtures, by L. A. Jones; Photographic Resolving Power, by P. G. Nutting; Light Filters for Use in Photometry, by C. E. K. Mees; The Color of Illuminants, by L. A. Jones; Transmission and Reflection Photometer for Small Areas, by P. G. Nutting and L. A. Jones; Reflecting Power Standards, by P. G. Nutting, L. A. Jones and F. A. Elliott; Axial Chromatic Aberration of the Human Eye, by P. G. Nutting; The Visibility of Radiation, by P. G. Nutting; Mixed Specular and Diffuse Reflection, by P. G. Nutting; The Sensitometry of Photographic Papers, by P. G. Nutting, L. A. Jones and C. E. K. Mees, and The Physics of the Photographic Process, by C. E. K. Mees.

Dr. Mees and his co-workers must be sincerely congratulated on the fine showing of this first volume. The papers were originally published in quite a number of different independent journals and are here collected somewhat abstracted. This is the correct practice if the object of papers is dissemination of knowledge rather than glorification of the laboratory or bureau from which they originated. There are some State and Government bureaus, and even others, that have still to learn this simple obvious truth.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, NOVEMBER 15, 1915 No. 14

Published Semi-monthly on the First and Fifteenth of Each Month by the

McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.

A. E. Clifford, Secretary. John T. DeMott, Treasurer

239 West 39th St., New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Col.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright. 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y.. under the Act of Congress, March 3, 1879.

Contents for November 15, 1915

EDITORIAL:
- Second Exposition of Chemical Industries..... 823
- Unprecedented Times in Steel..... 823
- A Little Confusion of Thought and Speech..... 824
- Saving Trouble in Handling Units..... 824
- While You Learn from Mistakes, Make Your Mistakes on a Small Scale..... 825

READERS' VIEWS AND COMMENTS:
- Chemical Engineering as an Independent University Course at Purdue. By H. C. Peffer..... 826
- Tube-Milling: Closed Circuit. By W. J. Pentland..... 826
- The Naval Consulting Board. By L. F. Vogt..... 827

Benzol and Toluol from California Oils..... 828
Nitrogen Fixation in Russia..... 828
The Willard Gibbs Professorship of Research in Pure Chemistry..... 828
Standardization of Metallurgical Units..... 828
The Aniline Dye Situation..... 829
American Iron and Steel Institute Meeting at Cleveland..... 830
Non-Ferrous Metal Market..... 831
The Iron and Steel Market..... 831
Thermal Principles of the Blast Furnace. By J. E. Johnson, Jr.. 833
Potash from Wood and Plant Ashes. By Harlow Bradley.. 841
Flotation of Joplin-Galena Slimes. By George Belchic and Glenn L. Allen..... 847
Electrolytic Antimony Refining. By Anson G. Betts..... 848
Gas Analysis..... 851
The Electrolytic Precipitation of Gold, Silver and Copper from Cyanide Solutions. By G. H. Clevenger..... 852
Manufacture and Tests of Silica Brick for the By-product Coke Oven. By Kenneth Seaver..... 861
Unstable States in Arc and Glow. By W. G. Cady..... 866
Notes on Chemistry and Metallurgy in Great Britain..... 869
Recent Chemical and Metallurgical Patents..... 871
Synopsis of Recent Chemical and Metallurgical Literature..... 873
Fused Silica Ware Made in United States..... 875
Chain Screen Doors for Oven and Furnace Openings..... 875
Bihn-Jones Automatic Air Device for Raising or Handling Large Quantities of Liquids..... 876
The Scientific Study of Steel..... 877
Personal..... 878
Book Reviews..... 878

Second Exposition of Chemical Industries

Le roi est mort, vive le roi. When the exceedingly successful First National Exposition of Chemical Industries passed into eternity a few weeks ago, quick action in preparing the next one became imperative, and we are glad to announce that at a meeting of the Exposition Management and its Advisory Board, held last week, it was definitely settled that the Second Exposition will be held from Monday to Saturday, September 25 to 30, 1916. The management will start at once in its work. But it seems to us that now is the time also for the different national chemical societies, representing the American chemical profession, to start in some preparatory work of their own. The Second National Exposition will undoubtedly be visited by a great many more chemists and engineers from all over the country than have come together anywhere in the United States for a long time. It would seem the logical thing for the national chemical societies to hold, each of them, a meeting—a regular or a special one—at the time of the Exposition in New York. Such a Chemical Convocation Week would be a delightful affair and would emphasize that with all their characteristic individualities which should be faithfully conserved, the different American chemical societies are a harmonious and enthusiastic unit in their ultimate endeavor.

Unprecedented Times in Steel

For the present situation in the steel industry there are no parallels in history. It is easy to make the comparison to test the accuracy of such a statement, for the steel industry as the principal purveyor of a wrought ferrous material is only about a quarter century old. It is scarcely twenty-five years, in other words, since the number of puddling furnaces in operation began to decrease.

Last November and December witnessed greater stagnation in the steel-making industry than had ever before been witnessed. The production of finished steel in December represented less than 35 per cent of the productive capacity. The production of crude steel slightly exceeded the production of finished material, as a few concerns were stocking ingots or billets. The production of pig iron reached a somewhat lower ebb still, as there was considerable stocking of pig.

Thus the market movement in steel is barely eleven months old, but wonderful things have occurred in that period. Since 1907 there have been two major movements in the steel market, in 1909 and 1912, but the present movement has already overtopped them. In the earlier stages of the present movement steel prices advanced at about the same rate as in those movements, but prices have now been advancing for

a longer period and the advance has become more rapid. Finished steel prices, on an average, are now about $2 a ton above the top reached in 1912, and are level with the top reached in 1909, and the curve of prices, instead of showing signs of soon rounding an apex, is trending still more sharply upward. Next we must consider the 1905-6-7 movement. Its top was $4 to $5 a ton above the present price level, but more than two years were required even to approximate that top. In the next preceding price movement, 1901-2, the advances were far from spectacular. In 1899 there occurred a "runaway market" but the spectacular feature was simply the fancy prices that were paid for relatively small quantities of steel for prompt shipment.

An outstanding feature of the present steel market is that as the weeks pass the steel mills are more and more reserved in the matter of booking contracts for forward delivery. Their transactions are being confined more and more to the making of specific sales, the buyer furnishing specifications and all details as to making shipment, which is to occur practically at mill convenience. This change in sales policy paves the way for rapid price advances.

Views as to the fundamental causes of the heavy pressure upon the steel mills have been changing rapidly in the past two or three weeks. When steel demand began to increase, in last December and the first two or three months of the present year, the common thought was that a reaction had naturally occurred, from an unprecedentedly stagnant condition, and there was doubt as to whether the improvement would last long. Later, in the summer, the demand for steel was regarded as very largely a "war demand." The development of the very recent past is that there is a very strong demand from strictly domestic sources for peace purposes, and the steel industry now staggers under its load, for the demand for war purposes is increasing rather than decreasing.

We shall now see tried out on a large scale the experience of a positive demand for steel with no restraint as to prices. For many years the policy of the steel trade had been to view the steel market as something that should be held steady, extreme advances or declines being regarded as highly objectionable. Price advances were likely to curtail consumption and price declines likely to disturb confidence, both therefore inviting disaster. From another viewpoint it might be argued that if the demand for steel is real, the need of each particular consumer should be weighed against the general demand; if it was less in intensity, that buyer should wait until he could buy at a lower figure, and thus there might be great fluctuations in prices, but little fluctuation in production. Such a theory has not found much support in steel selling circles, but a runaway market has been forced upon the industry and through no choice of anyone the experiment is going to be tried. As prices are now advancing, levels will be reached at which some consumers will certainly find it necessary to defer their purchases. Eventually they will have an opportunity to buy at lower prices, and if they take advantage of the opportunity the production of steel will be kept at a steadier rate than has been the case in the past. It may require years for the full period of the experiment but its progress will certainly be watched with intense interest.

A Little Confusion of Thought and Speech

In the profession of mining engineering there are such phrases as "ore in sight," "ore blocked out," "positive ore," "probable ore," "possible ore," to denote the differences between the expected and the actual and to help one to estimate in the mind the degree of certainty of evidence or of proof. The old adage, "There is nothing certain except death and taxes," leads us to believe that there is nothing given man between a reasonable expectation and futuristic determinism. In the chemical and metallurgical professions, where we all know the rapid change that is taking place, there is a similar difference between things as we hope they will be, things as we try to make them, and things as they actually turn out.

Possibly the forceful character of the American nation cannot often discriminate between things as people desire them in the future and things as they really prove to be. If a man repeatedly says, "I will get there" and "This shall happen," he in time may instill into his mind a certain self-confidence now so aptly termed "auto-suggestion." Possibly, indeed very likely, the widespread national looseness about the use of "will" and "shall" is derived from our somewhat egotistical state of mind. In the first person, "will" means "wish" or "desire," "shall" simple futurity, whereas in the second and third person the meanings are reversed and "shall" denotes desire or determination, while "will" means simple futurity. In colloquial speech, not one person in a hundred makes any distinction in the use of "will" and "shall," and the reason is probably that there is no difference noticed in the mind.

Indeed, it is not hard to detect in this fault of speech the fault of looseness of thought and immoderate egotism. Between the intense desire to have the future happen as one wills it and active efforts to make it, there is in one aspect—that of the personal equation—no difference. Fortunately, in the spoken word, the inflection of the voice tells much of the meaning of the speaker. In the written form a certain purity and precision of diction should tell one to be careful, for "nobody shall help me from mistakes of the pen, and I will drown in literary fashion," to paraphrase the classical example of the rhetorician, and in a scientific profession like that of the chemical and metallurgical engineer his language should be as precise as his thoughts.

Saving Trouble in Handling Units

In view of the universal present endeavor to do everything in the shortest possible time and to effect a standardization wherever possible, the psychological moment seems to have come to adopt single systems of units which will be used by everyone. Every engineer knows the extra work which he has had to perform in trans-

ferring from one to another system then back to the first system, and so on, thus increasing the probability of error every time a transfer is made. A good forward step in the right direction in regard to metallurgical practice has been taken by the Mining and Metallurgical Society of America, a preliminary report of whose committee will be found on page 828 of this issue. While everyone may not agree with all of the recommendations made, yet everyone will admit that the single system is the only system for rapid and efficient work and accurate intercourse.

The recommendations to use the metric system of weights and state the gold and silver contents of ores in decimal fractions, or in percentages and decimal fractions, wherever the metric system has been adopted as legal and in all Spanish-American countries, and the recommendation to use degrees Centigrade in a like manner are timely, as everyone who has used these systems knows their immense superiority. The ton, which in this country is so elastic, is recommended to be placed at 2000 lb. The bullion and assay value units should prove a great boon if commonly used. Several units which are in very common use, and have been so for a long time, could be changed in general practice only with greatest difficulty, and this is a great pity. It is to be deplored that the gallon is in such common use that it had to be recommended as a standard, also the "fluid ton," in the case of cyanide solutions, which is stated to closely approximate 2000 lb., instead of exactly equalling 2000 lb.

The recommendations are not intended radically to convert long-used units into units which have not been in general use in metallurgy, since, as before stated, it almost seems practically impossible to change current practice. The idea is to have one system, to adhere to that system, and to endeavor to bring it into general use. There are, however, so many different systems represented in the different units that it is hard to see how many laborious calculations can be avoided in the use of the present recommendations. They are, no doubt, the best for the present, but it is to be hoped that in the course of time we may talk only of liters, kilograms and other metric units.

While You Learn from Mistakes, Make Your Mistakes on a Small Scale

It is an easy and fascinating task to talk about the glories of a research or an invention—how the inventor sees a vision, goes into a trance, and does some quick, hard thinking, and lo and behold, he makes a model and a million dollars. Good brilliant ideas are easy and delightful, but the practicalization of these ideas is, as Rudyard Kipling says, "another story." Actually the popular imagination is far wrong; it sees only the glitter and glamor, not the tedious hard experimenting, not the financial troubles, not the difficulties that beset the path of the research pioneer.

What, indeed, is the keynote of success of a successful invention? And where shall we find the wisdom of the successful one and the understanding that, actuated by a will of iron, persists till the goal of commercial operation is reached? How does the idea become crystallized? There are many answers to this, all correlated and interdependent.

Possibly Edison's classic and laconic answer, "Genius is 2 per cent inspiration and 98 per cent perspiration," is as good a one as can be devised. What we would propose in the psychological atmosphere of the present days is somewhat different, and reads like this: "Make your mistakes on a small scale!"

This is good advice from a business standpoint, for all successful processes are founded on mistakes, and it is necessary to know by actual test where the pitfalls are in order to avoid them. If we assume the wisdom and truth of the slogan "make your mistakes on a small scale," we can adduce as a consequence this: act on your mistakes by the use of your imagination. The human mind is supposed to have several parts, or better expressed, different powers, by which it acts, but for progress or for full delight of life nothing is more a requisite than imagination, tempered by reason and controlled by common sense, for it is that mental ability that enables the possessor to project thoughts like a cinematograph on the screen of the soul. Without this ability to project, to extrapolate a curve far beyond the known, to take the known facts and find out and prove the existence of new facts, no inventor would succeed. And so in scientific transcendentalism do we find the peculiar mental trait that utilizes the past mistakes as stepping-stones to victory.

Now all this operation must be done commercially, for if the invention costs as much to produce as it is worth to society, there should and cannot be on the average any profit in the venture. So the truth of the remark: "Make your mistakes on a small scale."

While a strong motive in building on mistakes may be the personal gain of the interested parties, yet the secondary and often primary motive, if we are to judge by the effects, is the good that society will gain. This must be where the will to believe and the will to conquer has its source.

The personal equation naturally is the driving force. The ability to fight, to sacrifice himself and may be his family, to work with a smile at a thankless task—these are the victories of peace and "the moral equivalent of war." With the imagination apperceiving, there is associated a feeling or intuition, a full development of the feminine kind of thought that tells the inventor how to meet emergencies and how to foresee the future. A successful inventor tells us that at most critical times he acted against the advice of his friends and against his own logical judgment and was right. For in truth can it profit a man to make mistakes on a small scale or on a large scale and not learn from them?

It is in the commercial consideration of the subject that the element of cost must be held in mind. Large mistakes are expensive, small ones are cheap, but the inventor must learn. And he only learns and advances by use of a "will-pervaded" imagination that sees the unknown and attains the impossible. With all this idealistic side, the homely sentence, "make your mistakes on a small scale," blends in harmonious thought.

Readers' Views and Comments

Chemical Engineering as an Independent University Course at Purdue

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I note with interest the editorial comment in your issue of Sept. 1, relative to chemical engineering.

Supplementing the information contained therein, it may not be amiss to state that at this institution, Purdue University, the School of Chemical Engineering has since 1911 existed as a separate school on an equal basis with the other engineering schools of the university, and now numbers sixty-one graduates.

The course is attracting a superior class of men, and in spite of a very strict interpretation of entrance requirements, the present enrollment is 168.

The curriculum of the School of Chemical Engineering may be found on page 84 of the catalog of the university. It may be said in regard to the work of the junior and senior years that these are now in a period of transition which will result in physical chemistry being administered as a required subject, beginning with next year.

H. C. Peffer.

School of Chemical Engineering,
Purdue University, Lafayette, Indiana.

Tube-Milling: Closed Circuit

To the Editor of Metallurgical & Chemical Engineering:

Sir:—The discussion on tube-milling in your February number is interesting. Closed circuit would seem to be with us to stay, at least for quite a while; so were fine feeds and high discharges, but after a while they went their way.

There is no doubt that the economical result obtained should guide, and as shown in the discussion of the article by Mr. Haynes and his table of results, a cumulative load of 570 tons will give a net grinding to minus 200 of 58.59 tons. And the relative time that each ore particle is in the tube-mill may be fourteen minutes, that is, for each round; but does it not circulate six or seven times and in the end be eighty-four to 100 minutes in the tube-mill anyway? Is there any advantage in circulating pulp so much if the same result can be had without so doing? It costs something to return pulp to the tube-mill, even when using drag classifiers. Is there not something radically wrong with any system of crushing when it is necessary to return the pulp so many times in order to reach a desired result?

As there can be no argument over the crushing machine used; i.e., that the tube-mill, with its load of pebbles, furnishes all the elements necessary to successfully break or grind sand of six or finer mesh down to minus 200, we must look into the condition of the feed in order to find some condition that can be changed so that better results may be had.

In the earlier years of tube-mill experience it was generally thought that the feed—the battery discharge—had to be relatively fine in order that the tube-mill might be able to do its work. Thirty-mesh screen on the batteries was quite common. Nowadays most mills use coarse screen, six, eight, ten or twelve-mesh on the batteries. This change in general custom may be considered proof that tube-mills can successfully grind more net tons of coarse feed than they can of fine feed. It is in order then to find the reason why this should be so.

May it be that between two pebbles equal volumes of coarse pulp and of fine pulp will be caught, and in each case the total volume be reduced to ultimate size; and that the volume of coarse pulp weighing more than the same volume of fine pulp, there is a greater resulting tonnage ground in the case of the coarse pulp? I believe that this is what takes place, and while total volumes are not really ground at once to ultimate size yet equal proportions of such volumes will be ground, so the same relative result is obtained; more coarse pulp is reduced in the operation than would have been the case had the pulp been fine. This, of course, implies coarse feed, reasonable in size, such as the six-mesh and nearby sizes, when compared with the sizing of the pulp returned from the mill when fed with overload.

I cannot agree with any theory that a six-mesh particle of ore must go through a tube-mill five to seven times, being somewhat reduced on each passage, until it will finally emerge a 200-mesh particle. I think that if it once lodges between two pebbles in action it will at once be ground or broken so that the larger portion of it will be ground to minus 200, and the remainder will be approaching that size and must again be caught between other pebbles in order to be finished to 200-mesh. Poor grinding occurs because ore particles go through the mill without being caught between grinding surfaces and not because the force applied is insufficient to reduce the particles at one operation; there is an excess of force applied, but much of it is not utilized, as only those particles of ore actually between the rubbing surfaces are fully ground, and those particles that lodge just outside the points of contact get only partial grinding.

With pulps of mixed sizes of ore particles, the coarse sand will come into play or be exposed to grinding conditions before the accompanying fine sands. The coarse sand parts with its water more readily and clings better to the pebbles; its comparative diameter also is greater and there is less chance of its passing between the pebbles; a fine particle might escape entirely where a large one would be caught, and being caught it is at once reduced greatly to a finer mesh. In the succeeding part of the mill all ore particles are approximately of the same size, most of the fine feed going through without any grinding, and to that is added the fine stuff left from breaking down the coarse part of the feed, so we go on accumulating return load until the gross load fed to the mill is something out of all reason.

When we reduce an ore sample in a mortar with a pestle we reach a point in the operation where we can no longer apply force of impact and get any results: we must resort to force of abrasion. When we put the pulverized sample on the bucking board we do not strike the pulp with the muller, we rub it or rather grind it by abrasion. It is universal custom to reduce sands and ore pulps for assay purposes to sixty, eighty or 100-mesh by abrasion, yet in tube-milling many seem to think that to reduce such pulps to 200-mesh force by impact should be applied. And so they contend that the mill revolutions should be such that the pebbles fall clear of the upcoming load. With the body of the mill half full of fluid pulp there cannot be much force by impact expended when the falling pebbles reach bottom after passing through the thick pulp floating in the mill. With pulps as dilute as 38 to 40 per cent moisture most of the fine parts of the ore will be in suspension, due to the violent agitation, and the coarse sands will have settled to the bottom where they are ground by abrasion, not impact.

Grinding pans are in many places considered superior

to tube-mills for producing minus 200-mesh pulp; they crush by abrasive force, not by impact. If we wish to obtain abrasive grinding in tube-mills the revolutions must be so adjusted that the pebbles just begin to cascade, but the main body slides back over itself without falling clear.

Battery sand is of relatively small size when compared with the irregularities or projections on the surfaces of tube-mill pebbles. Sand caught between two pebbles struck together is more likely to escape crushing than to receive it; if the same two pebbles were rubbed together the sand would more likely be crushed than to escape, as the inequalities on the two pebble surfaces would more likely fit into one another than to rest on the points while in motion.

As to sufficiency of force applied, I think that the weight of the load of pebbles, coupled with the dragging exerted by the liners causing the pebbles to push one against another, is ample to crush ordinary six-mesh and finer sizes. If crushing of ¼-in. and larger sizes be attempted force by impact may be necessary.

In order to secure the fullest results in grinding, the character of the pulp should be such that no segregation of parts can occur; coarse sands, fine sands and the water should remain evenly mixed, then all sizes get an equal chance of entering the grinding zones. With dilute pulps the coarse sands separate and settle to the bottom, where they come into close contact with the pebbles. The fine sands tend to be held in suspension, float up in the main body of the mill, and get only casual contact with the pebbles. With pulps of around 30 per cent moisture no segregation of parts takes place—the whole pulp clings to the surface of the pebbles, is carried along with them throughout their travel, and gets every opportunity for being caught in the grinding zones. There will be less floating load in the body of the mill as most of the pulp will be traveling with the pebbles. It will probably cause an unbalanced load and require more power to turn the mill, but there will be no cushioning of the grinding forces if "cascading" be practiced—every pebble works every moment. I think that with cascading of the pebbles 90 per cent of the grinding done is accomplished by abrasive force exerted between the pebbles in the bottom of mill and on the uphill movement. With 38 per cent moisture no clinging of the pulp to the pebbles can occur; sands settle out quickly and are ground while in the bottom of the mill, the fine product then rising to float in suspension with the main body of the pulp.

Scoop-feeding solved all the troubles incidental to charging thick pulps into tube-mills; low discharges solve those incidental to passing thick pulps through tube-mills. Thirty per cent moisture pulps will not flow freely in launders, but screw conveyors will pass them. Thirty per cent pulp comes out of the tube-mill as a thick ooze, lining the chamber 2 in. thick, but this can be diluted by a hose playing on the outside of the cylindrical screen. We found that 25 per cent moisture pulp would work through a mill having 18-in. discharge end, but could not maintain an even flow with as much tonnage as the mill would fully grind; we could maintain the flow for hours at a time, long enough to determine to our satisfaction that such low moisture would be desirable if we could overcome the mechanical difficulties of handling it. We thought that with lower discharge we could have obtained the tonnage desired, and with open circuit. With 30 per cent moisture we could maintain an even flow of pulp, but the tonnage desired could not be reached, though we did obtain better than 80 per cent through 200 mesh.

According to the experiments of W. B. Easton, with a mill equipped with lifter devices he obtained 70 per cent through 200 when passing 144 tons through it with open circuit, and with 240 tons gross, closed circuit, he obtained 72 per cent through 200 mesh. These are figures that I believe have never been equalled in tube-mill practice. I would take it that the moisture contents were 38 per cent and 40 per cent, and would like to have seen his results when passing pulp of low moisture. His experiments would indicate that, with low discharge, sufficient feed of any moisture can be passed through a mill in quantity to overload, and that consequently the closed circuit cannot be dispensed with entirely; but when net grinding to minus 200 reaches such figures as 70-odd per cent it would seem that it would be better to work one or perhaps two tube-mills, following in series to take the concentrated return from all the primary mills.

The figures given by Mr. Easton concerning minus 200-mesh product are all in conjunction with 38 per cent. and 40 per cent moisture pulps; we would like to have had some of his figures or results of passing low-moisture pulps. His comments on low moistures would infer that he favored them for their grinding effects; he declares himself in favor of them as regards their requiring lower power consumption, and he also states that fuller loads develop lower power consumption. I am inclined to think that the effect of the lifters will be to extract the top of the floating load in the mill first, and thereby lower the moisture content of the charge of pulp in the mill at a given moment. I consider the lifter device the greatest improvement in tube-mill design that we have seen in a long time.

Guadalajara, Mexico. W. J. PENTLAND.

The Naval Consulting Board

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I have read with interest the current literature and news in regard to the Naval Consulting Board and it has occurred to me that the question might well be raised in connection with this whole matter as to why the Consulting Board should devote its attention only to naval matters, as apparently intended, rather than to both Navy and Army needs. The step taken is in the right direction and will undoubtedly produce splendid results, will promote patriotism and promote in general a personal interest in the affairs of our country such as has been lacking to a large extent in the recent past. In general it seems that our government has been left too much to the politicians.

Without doubt the wonderful success of the Germans at the present time is due to the fact that they make the most of the technical skill and scientific brains available in the German Empire. In our own country Army and Navy matters have been left largely to inexperienced men and those who may be in more or less of a rut in the government service. The best men of the country have been employed in industrial pursuits almost entirely and have not apparently devoted much attention to our national protection, and national protection should came first in as much as our industrial success is dependent upon this.

Why should not the Consulting Board's Navy Research Laboratory be a joint Navy and Army undertaking? It would seem that there could be only one answer to such a question. L. F. VOGT.

Standard Chemical Co.,
Canonsburg, Pa.

Mineral production in California in 1914.—The complete detailed report of the mineral yield of California for 1914 compiled under the direction of Fletcher Hamilton, State mineralogist, is now ready for distribution in the form of Bulletin 70 of the State Mining Bureau.

Benzol and Toluol from California Oils

The Standard Oil Company of California is producing now on a small commercial scale the much cherished benzol and toluol.

Strictest secrecy is maintained as to methods applied in producing from the California crude oil, which has an asphaltum base, these materials so much needed in the dye industry, as well as in the explosive manufacture.

Apparently there is a very handsome profit in the manufacture, and there is some talk of the oil company eventually entering into the dye industry.

Another new product the Standard Oil Company of California has to its credit is a product sold under the trade name of "*calol*," a perfectly water-white, tasteless and stable oil used for medicinal purposes.

The famous British surgeon, Sir Arbethnot Lane, who discovered "kinks" in the intestines of human beings, found that in milder cases it was not necessary to operate, but that the "kinks" could be overcome if a suitable internal lubricant could be supplied. "Russian oil" was the remedy, but since the war this supply has been cut off, and many inferior substitutes have been placed on the market. After lengthy experiments an oil has been produced by this company which is equally good and has even been pronounced better than the Russian product.

The demand for the product is great, and while the large plant is being built a small temporary plant is operating to its capacity, not beginning to be able to fill orders.

The world's demand of this internal lubricant is being supplied at present from California and from California crude oil.

Nitrogen Fixation in Russia

It is reported in Scandinavian papers that a large company with strong capital backing has been formed in Russia for the purpose of manufacturing nitrates from the nitrogen of the air.

The process to be used is the well-known Birkeland and Eyde process.

All arrangements with the Norwegian company, owners of the Birkeland and Eyde patents, have been made and a plant is being built in the North of European Russia, off the White Sea.

It is interesting to note Russia's entering the electrochemical field in this manner, and also that through dire necessity of war an industry is started that in time of peace produces products that are a blessing to the inhabitants of its country, and in war times produces the same products, but they are then no blessing, but rather a curse to the inhabitants of adjoining countries, "Les extreme ce touche."

The Willard Gibbs Professorship of Research in Pure Chemistry

In course of the academic year 1914-1915, a new department was established on a permanent basis in the Mellon Institute of Industrial Research of the University of Pittsburgh, namely, a Department of Research in Pure Chemistry. The headship of this department is to be known as the Willard Gibbs Professorship of Research in Pure Chemistry, "to ever proclaim the ideal which the incumbents of the chair and the groups of research workers to be associated with them will be expected to follow." It constitutes a chair in the Graduate School of the University of Pittsburgh as well as in the Mellon Institute.

Dr. Martin A. Rosanoff, who had built up and for years headed the Graduate Department of Chemistry in Clark University, was formally inaugurated as the first permanent incumbent of this professorship, at exercises held in the Assembly Hall of the Mellon Institute on Oct. 26. The exercises included addresses by Prof. James McKeen Cattell and Prof. Marston Taylor Bogert, both of Columbia University, and by Dr. Rosanoff, followed by a reception and an inspection of the Mellon Institute.

Chancellor Samuel Black McCormick presided at the exercises. He explained the circumstances connected with the establishment of the chair and thanked the donors whose generosity had made possible the endowment, of which the income is to constitute the salary of the incumbent of the chair. He then introduced Dr. Cattell.

Standardization of Metallurgical Units

A preliminary report of the Committee on Standardization of the Mining and Metallurgical Society of America contains suggestions pertaining both to mining and metallurgical matters. We give below those recommendations relating particularly to metallurgy.

Mesh of Wire Cloth.—The standard mesh of the Mining and Metallurgical Society of America shall be the standard screen of the W. S. Tyler Company of Cleveland, Ohio, as described in that company's catalog No. 36. The basic screen of this scale has an opening of 0.0029 in., which is assumed to be equal to 200 mesh. The opening in each successive screen increases in the ratio of the square root of 2, or 1.414.

This furnishes a standard screen scale in which the area of each successive opening in the scale is doubled that of the second preceding.

The dimensions of the Tyler screens are as follows:

Openings		
Millimeters	Inch	Mesh
26.67	1.050	
18.85	0.742	
13.33	.525	
9.423	.371	
6.680	.263	3
4.699	.185	4
3.327	.131	6
2.362	.093	8
1.651	.065	10
1.168	.046	14
0.833	.0328	20
.589	.0232	28
.417	.0164	35
.295	.0116	48
.208	.0082	65
.147	.0058	100
.104	.0041	150
.074	.0029	200

Weights and Measures.—1. For all Spanish-American countries, and all other countries where the metric system of weights is the legal one, a statement concerning measures and weights of whatsoever kind shall be in the metric system.

All references to temperature shall be in degrees Centigrade.

In Spanish-American countries and in all other countries which have adopted as their legal standard of weight and measures the metric system, the gold and silver contents of ores, alloys, bullion or other materials, must be stated in decimal fractions of the weight of the material, or in percentages and decimal fractions thereof or else in kilos of silver and grammes of gold per metric ton of material.

2. The word "ton" shall represent a weight of 2000 lb. avoirdupois (29,166.6 oz. troy).

It is advisable to abandon the use of such terms as "hundredweights" and "quarters," and to express fractions of a ton in pounds or decimals of a ton.

3. The term "miner's inch" shall represent a flow of 1.5 cu. ft. of water per minute. Where this unit is not customary and currently acknowledged, the flow of water shall be expressed in cubic feet per minute or per second.

4. In the United States the unit of liquid measure is the standard gallon of 231 cu. in. In England, and the British colonies which have legalized the unit, the "Imperial gallon" measure of 10 lb. of water is to be used.

In every case all reports should state definitely which gallon is used therein.

5. Temperature should be expressed in degrees Centigrade. Subsidiary use of the Fahrenheit scale is admissible; but only conjointly with the Centigrade scale and not alone.

6. Returns of gold and silver shall be expressed in terms of fine gold and silver respectively, not as "bullion."

7. Gold and silver contents of ores determined by assay may be expressed in money values per ton of 2000 lb. avoirdupois, as well as in weight per ton. In this connection the value of gold shall be taken at 85s., sterling, or $20.67 U. S. currency, per troy ounce of fine gold.

All other constituents of alloys, metallurgical products, or other material must be given in percentages of the substances analyzed.

It is to be noted that certain commodities, such as pig iron, steel rails or large sections, etc., are dealt in in various arbitrary units. Where it is a recognized custom of the trade to use such special unit, statements therein are permissible, but provided, however, that it is always clearly stated what the unit be in some other and standard unit.

Bullion and Assay Values.—The following is proposed concerning these terms:

1. All samples should be dried at 100 deg. C. before being submitted to assay or analysis and reports should definitely state that this precaution has been taken.

2. Assay values of gold and silver ore and products should be represented in ounces and decimals and not in ounces, pennyweights and grains. They shall always be expressed in terms of fine gold and silver respectively and not as "bullion."

3. Assay values of alluvials shall be reported in grains and decimals of a grain of fine gold, or in pence (at 2d. per grain of fine gold), or in cents per cubic yard.

It is recommended that, in the absence of specific information as to boulders, etc., 1 cu. yd. of ordinary alluvial be taken as equivalent to 3000 lb. (1.5 short tons).

4. In reporting assay values of cyanide and other solutions, the results shall be given in parts by weight in a stated volume of the solution.

In the case of cyanide solutions, the use of the "fluid ton of 32 cu. ft." is recommended. It closely approximates to 2000 lb. and is in common use.

5. When it is necessary to state or estimate the money value of an ore, etc. (other than gold), the contents shall be given in percentages of the base metals, and in ounces of gold and ounces of silver.

If it becomes necessary to estimate the value of the ore in money the first step would be a deduction from these percentages to allow for metallurgical losses and the next following step the calculation of the value of the recoverable metals at definite fixed prices. If the net value of the ore is required then from the above should be deducted the working and realization costs.

6. We recommend for all laboratory sieving the Tyler standard screens.

The Aniline Dye Situation

In the account of Mr. I. F. Stone's paper before the New York Section of the American Chemical Society in our issue of Oct. 15 (page 710), the statement on the increase of aniline dyes manufactured in this country was incorrectly reported. We quote the section in question verbatim from Mr. Stone's complete paper:

"Another large increase in production through the present conditions is the manufacture of aniline colors and other coal-tar products in this country, which will be much to the relief of consumers, who at the present time are unable to get anything like the supply of colors which they need in the conduct of their business. The five factories already established in this country before the war are all extending their production to their utmost capacity in keeping with safety for their investment, and I believe that in 1916 the production of aniline colors in this country will be at least three to four times the production before the war.

"This production could again be largely increased if the manufacturers were sure of some protection from the Government in the way of higher tariff or Government manufacture of intermediate materials, which would enable them to get the same at the same price as paid by European manufacturers, and then again, the putting into effect of some anti-dumping clause, which is now promised by the Government, to prevent the dumping into this country of colors at lower prices than they are sold elsewhere for the purpose of preventing their development and manufacture here.

"Whatever the Government may finally decide to do toward the protection of this industry, there remains the fact that a great impetus in the development is already under way, with the hope of Government protection, so that the Europeans will find them strongly entrenched in any event after the close of the war. I am speaking now of the factories already in operation, but in addition to these there are many new factories projected and some in operation. I have a list of twenty-three new factories, the last of them with a proposed capital of $15,000,000, and while a good many of these may not materialize, something will surely come of some of them.

"Up to now none have actually manufactured any aniline colors, but some are operating with a production of some intermediate products like aniline oil, beta-naphthol, paranitranilin, etc., and speaking of aniline oil, with the one factory established before the war and the increase in its works since the war, and the number of new factories making or about to make aniline oil, it looks as if the production of this product would be 8000 to 10,000 tons, as against the normal consumption of about 4000 tons; in other words, the proposed manufacture seems larger than the consumption, but as the consumption is also increased possibly the whole amount projected can be used. At any rate, there will be enough manufactured in this country to take care of the whole consumption, so that Europe need not be depended upon."

* * *

With respect to the report of Dr. THOMAS H. NORTON'S paper before the New York Section of the Society of Chemical Industry (page 780 of our issue of Nov. 1) it should be stated that Dr. Norton made no direct recommendation of a Government factory for the production of coal-tar intermediates. What he did say in reference to Mr. Stone's plan in this respect was as follows: "The various admirable features of the plan, including the well-organized preparedness for the speedy manufacture of explosives and munitions generally, in case the nation be menaced by invasion, render the project worthy of the most careful study."

As to the proposed league of American consumers of dyestuffs, Dr. Norton did not recommend that all consumers who would purchase imported dyes at dumping prices should be penalized or ruled out altogether. He said: "It can also be easily seen that a powerful weapon is put into the hands of those who collectively represent the consumers of colors, to rigidly rule out from the

sources of supply any manufacturer, foreign or domestic, who would deliberately make an attempt to undersell his American rivals, or who would resort to any method of unfair restriction of trade."

American Iron and Steel Institute Meeting at Cleveland

The ninth general meeting of the American Iron and Steel Institute held in Cleveland, Oct. 22 and 23, was a success in every particular. The meeting was a record breaker in attendance, about 680 having registered during the two days. The reduced number of papers was a pleasing feature and helped to sustain the interest and discussion. On Friday evening a banquet was held at the Hotel Statler, at which moving pictures were shown of manufacturing processes at the plants of the National Tube Company and the American Steel and Wire Company. After this feature, Judge Gary called on a number of prominent members for short addresses. Saturday morning several hundred of the members enjoyed a visit to the plant of the White Company, and a special train was provided to take the members to the Pennsylvania ore dock, where the unloading of the "J. P. Morgan" of the Pittsburgh Steamship Company, was witnessed.

The first session was opened Friday morning with an address by Judge Elbert H. Gary, in which he laid special emphasis on publicity, on the harm done to large corporations through their failure to take the public into their confidence. "The general public and private individuals have been in the past too far apart for the good of both. Lack of knowledge often breeds unnecessary and hurtful antagonisms, and many have suffered even though they were not personally at fault." . . . "There should be published whatever of business matters the public is legally entitled to know and also whatever may affect the public interest and may be exposed without detriment to the corporation or individual concerned." Judge Gary said we should have protection against the results of cheap labor and impoverished conditions abroad, in order to enjoy continued prosperity after the war.

Mr. Samuel Mather, chairman of the local committee, was the first speaker called on by Judge Gary. Mr. Mather spoke of the history of Cleveland and the development of the steel industry. Cleveland ranks fifth among the cities of the country in the value of manufactured products. It was owing to the discovery of copper and iron ore in the upper peninsula of Michigan in 1844 and the opening of the Sault Ste. Marie canal in 1855 that the great growth of Cleveland ensued, for this city then became the natural meeting place of the bituminous coal from the coal fields of southern Ohio, Pennsylvania and West Virginia, and the iron ore from the Lake Superior district. At Cleveland there are ten blast furnaces with an average output of 120,000 tons monthly, and an exceedingly great variety of manufactured products.

In a paper on, "Modern Methods of Burning Blast Furnace Gas in Stoves and Boilers," Mr. Ambrose N. Diehl gave the results of exhaustive investigations made of stove and boiler operation. The lack of accurate data among those using blast furnace gas made the problem more difficult. In considering the efficiency of a burner it is necessary to distinguish between the performance of the burner alone and that of the unit consisting of the burner and stove. A standard of efficiency which could serve as a basis of comparison was defined as follows: "A gas burner is operated at 100 per cent combustion efficiency when the analysis of a sample drawn from a point 2 ft. beyond the point of ignition, shows perfect combustion." Mr. Diehl's paper was exceptionally complete and the data presented are of considerable value, since the proper utilization of blast-furnace gas with relation to burner construction is an important subject which is receiving more attention. Mr. Diehl's paper was presented in abstract. Burners were classified into six types and their application to hot-blast stoves was first considered and a record of a number of tests was given in detail, with a similar treatment of gas burners for boilers. Most of the tests failed to show data in which the burner was isolated from the boiler or stove so that the data could only serve as a basis for study or adaptation to local conditions.

In the discussion of this paper Mr. H. P. Howland concluded that "for use on stoves we believe the pressure burner to be preferable. Regarding boiler burners, first, the point of automatic regulation as emphasized by Mr. Diehl, does not seem to us to be vitally essential; second, it should be admitted by all that a big step in advance has been taken in equipping a boiler house with burners capable of easy hand regulation in the place of the so-called common burner."

Mr. A. E. Maccoun agreed with Mr. Diehl that there was no type that has so far been developed which might safely be called the most efficient burner, but that only testing out would decide the best type to use.

In a paper on "The Development of Commercial Alloy Steels," Mr. Edgar D. Rogers: reviewed the history of alloy steels and showed how they came into commercial use. He said that Hadfield justly designates the year 1888 as the beginning of a thorough knowledge of alloy steels, when the use of silicon and manganese for the improvement of the physical and magnetic qualities was made practical. The chromium steel industry was founded in America by Julius Baur, and its use has become very extensive. Nickel steel was given an impetus in 1889 by Mr. Riley's paper before the British Iron and Steel Institute, and its use is established and increasing especially in automobile construction. Vanadium for steel was made commercially available when a vast deposit was unearthed in South America in 1905, and its properties are well known, in high-speed and anti-fatigue metal.

As to specifications Mr. Rogers said it had been his experience to receive orders on which certain chemical limits that were commercially possible were outlined, and then physical results demanded that were absolutely impossible with the prescribed analysis. The discrepancies are in a good measure due to the steel makers themselves because only a few years ago the data at hand on alloy steels were obtained through tests in which the type of steel was the only variable. He predicted that the next few years would show a greatly increased demand for alloy steels, and said the electric furnace has enabled the manufacturer to duplicate many steels which were formerly made in the crucible and at a reduced cost.

A paper on "Heat Treatment in Automatic Electric Furnaces" was presented by Mr. Thaddeus F. Baily. Mr. Baily reviewed the development of heat treatment and showed how it became necessary to devise an automatic electric furnace in order to remove the human element as much as possible. He then described a complete equipment and its operation. "The important element in the operation is the temperature measuring devices adopted to take the temperature of the material under treatment itself, not the furnace temperature." These special pyrometers actuate the interlocked electrically operated hydraulic valves when the proper temperature has been reached and discharge the material for quenching.

In the discussion Mr. S. T. Wellman suggested that the mechanism be operated electrically.

Dr. J. W. RICHARDS said that automatic heat treatment eliminating the personal factor of the workman, is a great step in advance. With proper design and heat insulation, electric furnaces of the Baily type should be capable of putting into the articles to be treated 50 per cent of the heating energy of the current. A combined fuel and electric furnace with electric heating for the last 100 or 200 deg. might be much cheaper in some localities. There seems no doubt that some such device would improve rolling practice by discharging ingots from the furnace always at the proper temperature.

Mr. Baily, in replying to the discussion, stated that their furnaces under observation had shown a thermal efficiency of 92½ per cent. In reply to a question by Dr. A. S. Cushman as to the arrangement of pyrometers, Mr. Baily advised placing the tube ½ in. from the metal at the point of discharge, and to Dr. Cushman's statement that surface temperatures were not a correct indication of interior temperatures, Mr. Baily said they allowed such a liberal period for heating that the piece was heated throughout uniformly.

A paper on "Control of Piping and Segregation in Ingots," was presented by Dr. HENRY M. HOWE, explaining the more important elementary principles by which piping and segregation in steel ingots may be lessened, in his characteristic lucid style.

In discussing this paper Mr. E. R. KEENEY said: "Dr. Howe has given us an explanation of many of the features which we have observed in the cooling of ingots, and in the main his reasoning is corroborated by our observations. His statement that during the whole of the preneutral period (i. e. the period during which the outer parts cool faster than the inner) the contraction of the outer parts tends to be more rapid than that of the central ones, is not necessarily true. It would depend on the relative coefficients of contraction of the two parts." Another point on which Mr. Keeney was not convinced was the effect on segregation of the upward currents caused by the gas bubbles in rising steel.

A paper on the "Mechanical Development in Sintering Materials" was presented by Mr. BETHUNE G. KLUGH, showing the intricate problems which were overcome in working out a simple process and describing the progress made in developing the continuous down-draft sintering machine of Dwight and Lloyd. In the discussion Messrs. Robert E. Brooke and Hermann A. Brassert gave their experiences with the Dwight-Lloyd machine. A paper on "Under-Advertising of the Steel Business" was presented by Mr. GEORGE H. JONES.

Non-Ferrous Metal Market

Copper.—The last week in October and the first week in November saw little change in copper prices with only a fair demand. Electrolytic rose slightly on Oct. 28, being quoted at 17.75@18 delivered terms. On Nov. 1 it rose slightly again and producers were asking 18@18.25, which price remained steady during the first week in November. Some authorities think the price was raised to induce buying instead of the usual practice of allowing concessions; in other words, what is known as a bull campaign was thought to be on. There have been 10,000,000 lb. removed from the regular monthly supply on account of the shut down of Greene-Cananea and the strike at Clifton, Ariz. The total exports from Atlantic ports during the month of October were 23,657 tons of 2240 lb. (compiled by N. Y. Metal Exchange). The output of the northern Michigan mines for October was 24,949,000 lb., the largest for any month this year. Exports so far this month have been very low, only 79 tons having been reported up to Nov. 5. Prices quoted on Nov. 5 were: Prime Lake, 18@18.25; Electrolytic, 18@18.25; Casting, 17.50@17.75. Standard in London was still £15 below Electrolytic.

Tin.—The tin market during the last of October and first week in November showed a gain of approximately 3 cents per pound. Quotations of the N. Y. Metal Exchange Oct. 20 for spot were 33.12½@33.50. On the 27th it rose to 33.62½@33.87½. By Nov. 1 it was 35.50@36.50, and on Nov. 6 Straits or Malacca tin was quoted at 35.95@36.37½. During this period the London market showed a steady advance, Straits tin rising from £153 to £162 5s. from Oct. 20 to Nov. 6, with a corresponding advance in Standard. The continued advance in London was thought to have been caused by the scare of shipments being endangered. The talk here of an export duty and the endangering of shipments probably also had its effect. Arrivals during October were only 2000 tons, with arrivals in November up to the 6th, 865 tons. The next two months are normally considered dull ones in volume of consumption.

Lead.—Lead has seen three advances since Oct. 20. On the 21st the Trust price was advanced 0.25 cent to 4.75. On the 29th a 0.15 cent advance was made to 4.90, and on Nov. 4 another advance was made to 5.00. The reasons given for these advances were the continued demand for export, and also an increasing demand for home consumption, the sheet lead trade being reported as very good. Lead was quoted Nov. 5 at 4.92½ at St. Louis, which is the usual differential. The total exports for October were 4106 tons with exports so far in November very low.

Zinc.—Spelter has advanced considerably since Oct. 20, when it was quoted at 13.50@13.75 for spot, with November at 13.00 and December at 12.50. During the last week in October large tonnages were sold for export and the price rose steadily to 14.67½@14.80. Towards the first of November the market became dull, but remained firm, however, and on Nov. 4 the demand became more active with prices at 15.17½@15.42½ spot and futures higher than previously.

Other Metals.—Of the other metals aluminium advanced during the last two weeks and is now quoted 56@58 for Virgin metal. Antimony rose from 30.50 on Oct. 20 to 35@35.50 on Nov. 6. Silver was then quoted at 50, nickel at 45@50, and quicksilver at $100 flask.

The Iron and Steel Market

Spectacular movements are occurring in the iron and steel markets. All precedents are violated and physical conditions, not trade practices or theories as to what is the best for the industry, are making the market from day to day. There are two dominant factors, that steel is extremely scarce, and that there is a heavy demand for special steel, chiefly for war purposes. The unprecedentedly heavy demand for steel as a whole makes it that finished steel products advance rapidly in price, and the commodities advance *pari passu*, because it is not the demand for the particular finished product, but the scarcity of the crude steel, that causes the advance. The large demand for special steel makes it that the ordinarily self contained operations, producing steel for their own consumption, in many cases buy soft steel for their own finishing mills and use their steel making equipment for the production of special steel, chiefly in the form of billets. The Pittsburgh Steel Company has bought about 40,000 tons of Bessemer billets, for use in its wire departments, thus releasing some open-hearth capacity for the manufacture of special steels. Several steel and sheet mill interests have bought sheet bars for their sheet mills and are selling special billets.

The war demand for steel is increasing, and is running to new products, there being offered large orders

for steel sheets, for trench covering and other purposes. The strictly domestic demand has increased sharply, the railroads being the most conspicuous buyers.

The making of contracts for future delivery of finished steel, subject to specifications to be furnished at intervals, has been greatly decreased. Many mills, perhaps the majority, have stopped making contracts entirely and are accepting business only in the form of specific orders.

Finished steel prices have been advancing rapidly, and by an average of not far from $2 a ton in the single fortnight. Unfinished steel is advancing likewise, but close comparisons cannot be made as the market is not well defined. Some consumers are regular customers and are given preference, while there is a sharp divergence between Bessemer and open-hearth steel, and another and still sharper divergence between ordinary soft open-hearth steel and steel that is in any respect special either as to composition or method of rolling.

Pig Iron

In the first few days of November there was a wave of buying of Bessemer and basic pig iron by central western mills, at but slight advances over the market previously current. Subsequent to these purchases the market has advanced rather sharply, the point being reached at which doubts arose whether the production of pig iron by merchant furnaces could be materially increased. In the earlier months of the general market movement there was always in sight a large number of idle merchant furnaces. While steel prices are now as high as at any time since the 1905-6-7 movement, pig iron has not yet reached levels attained in the 1909 and 1912 movements. With the present very sensitive market, however, new price levels may be attained very shortly. The market is now quotable as follows: No. 2 foundry iron, delivered Philadelphia, $16.50 to $16.75; f.o.b. furnace, Buffalo, $16 to $16.50; delivered Cleveland, $16.30; f.o.b. furnace, Chicago, $17 to $17.50; f.o.b. Birmingham, $13 for prompt and $13.50 for first quarter; f.o.b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $17; basic, $16; foundry and malleable, $15.50 to $16; forge, $15 to $15.50.

Steel

The large purchases of Bessemer billets by the Pittsburgh Steel Company, about 40,000 tons, together with the diversion of much finishing capacity to the use of Bessemer instead of open-hearth steel, has served to make a real and an advanced market for Bessemer billets, at $25.50 to $26.50, maker's mill, Pittsburgh or Youngstown. Bessemer sheet bars are about 50 cents higher. Open-hearth steel is about $1 a ton higher than Bessemer, but the curious condition exists that billets are likely to show a larger spread than this and sheet bars a smaller, peculiar conditions existing as some steel mills have recognized regular customers for sheet bars, while ordinary purchasers of billets do not have recognized sources of supply to the same extent. Ordinary forging billets command $42 to $45, while war billets command $50 to $60. Wire rods are about $35.

Finished Steel

Nearly all finished steel prices have advanced in the past fortnight. Prices now quoted are chiefly for shipment at mill convenience, against specific orders, there being few contracts. Premiums are frequently paid for particularly prompt shipment. Prices quoted are f.o.b. Pittsburgh unless otherwise noted:

Rails, standard sections, 1.25c for Bessemer, 1.34c for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.60c.

Shapes, 1.60c.

Steel bars and bands, 1.60c, base; hoops, 1.75c.

Iron bars, 1.659c to 1.759c, Philadelphia; 1.45c, Chicago; 1.50c to 1.60c, Pittsburgh.

Plain wire, 1.70c; wire nails, $1.85 per keg, base; painted barb wire, 2.00c; galvanized barb wire, 2.70c; fabricated wire fence, 69½ per cent off list, in carload lots.

Sheets, blue annealed, 10 gage, 1.80c to 1.90c; black, 28 gage, 2.25c to 2.35c; galvanized, 28 gage, 3.80c to 3.90c; painted corrugated, 28 gage, 2.45c to 2.50c; galvanized corrugated, 28 gage, 3.85c to 3.95c.

Tin plate, $3.30 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 78 per cent off list; galvanized, 63½ per cent off list.

Boiler tubes (less than carloads) 3½ to 4½-in., 69 per cent off list.

Structural rivets, 2.25c; boiler rivets, 2.35c.

The Chicago Pneumatic Tool Co. has issued a small booklet describing its Simplate flat disc valves which are used in its pneumatic compressors.

The Bristol Company of Waterbury, Conn, was awarded the Grand Prize at the Panama-Pacific Exposition for its exhibit of recording instruments. This exhibit was described in our issue of June, 1915.

The Swenson Evaporator Co., Chicago, Ill., reports that its evaporators are or will be soon installed for producing potash in the United States from all sources, viz., kelp, liquor, natural western lake waters, bittern, feldspar, molasses waste, and alumnite.

Gas Manufacture.—In Technical Paper 120 recently issued by the Bureau of Mines a bibliography of the chemistry of gas manufacture is given. It is intended to serve as a reference guide for those interested in gas making. The authors are W. F. Rittman and M. C. Whitaker.

Aluminium.—It has been reported that the Southern Aluminium Company's plant, work on which was stopped at the beginning of the war on account of the preponderance of foreign capital, has been sold to the Aluminum Company of America. The consideration was said to be about $6,500,000, and work is reported to have been started to finish the plant.

The Simonds Mfg. Co., of Fitchburg, Mass., has signed contracts with the United States Steel Corporation for license of a 5 to 6 gross ton Heroult three-phase electric melting furnace. Results obtained in experimenting and practical use of electric furnaces in the past five years have indicated the desirability of installing the present furnace, which is expected to be under power by January, 1916.

Coal and Mining Laws.—It has been estimated that there are more than 3,500,000,000,000 short tons of coal in the United States, exclusive of Alaska. In mining a comparison with the practices of other countries is helpful. Geological Survey Bulletin 505, "Mining Laws of Australia and New Zealand," contains much suggestive information. This report may be obtained free from the Director of the Geological Survey at Washington, D. C.

Lime Production in 1914.—The total lime manufactured and sold in the United States in 1914 was 3,380,928 short tons, according to the U. S. Geological Survey. This was valued at $1,400,686. Both the quantity and value for 1914 are less than for any previous year since 1908. Lime for chemical works showed a decrease of 20,872 tons from 1913, and a decrease in value of $137,050, owing to a drop of 18 cents in the average price per ton. Both quantity and value, however, exceeded those of 1910, 1911 and 1912.

Thermal Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

(*Continued from page* 792)

Returning now for a moment to the comparison of the theory of the blast furnace with thermodynamics it may be shown that what may be called the availability factor can be expressed in the same mathematical terms in both cases.

The second law of thermodynamics is expressed by the formula $Q \times \frac{T_1 - T_2}{T_1}$, in which Q is the total quantity of heat concerned in the transformation, T_1 is the temperature at which it is applied and T_2 is that at which the unused portion is rejected.

Now in the blast furnace if the whole quantity of heat developed in the hearth be Q, the theoretical combustion temperature be T_1 and the critical temperature be T_2, since the heat given out by a gas in cooling is proportional to the temperature drop $T_1 - T_2$, the portion of the whole which can be utilized in the hearth is $\frac{T_1 - T_2}{T_1} \times Q$, exactly the same as in the case of steam engine.

This is in one sense only a matter of casual interest, but in view of the increasing connection recognized between chemistry and thermodynamics it is highly suggestive. It will be noted that the idea that there are two heat balances for each furnace, one for the shaft, the other for the hearth and bosh, is set forth very plainly in the quotation before given from "Notes on the Physical Action of the Blast Furnace," but the difficulty of getting at the debit side of the account seemed almost insuperable, and on this account I did not for several years use the chart of hearth heat for any but comparative purposes to show the heat obtainable per pound of coke with different blast and critical temperatures and different percentages of moisture in the blast, because the furnaces of which I had the management were coke furnaces on relatively lean ores, and in such cases the hearth heat obtainable per pound of coke exerts exclusive control of the economy of the furnace when other details of operation receive proper attention.

A few years ago when I undertook the management of a charcoal furnace using rich ores I attempted to apply the same principles and methods of calculation to it, but soon found that there were many features of its operation which could not be explained on that basis.

For instance, covering in the ends of the blowing cylinder and piping the air to it from out of doors in a very dry climate yielded no better results than taking the air from the engine room, although figures from the chart of hearth heat based on the humidity in the engine room indicated that a considerable saving should result. Similarly, changes of blast temperature exerted little or no influence on the running of the furnace compared with what similar changes would do on a coke furnace, and in particular it seemed impossible to save the furnace by the use of more blast heat when it started to run cold. It was absolutely necessary to put more fuel down into the hearth.

Finally it occurred to me that the hearth heat per pound of iron generated in that practice might be greater than was needed, and that a comparison of that developed in charcoal practice with that developed in coke practice might be illuminating. I had been taking observations of the free-running temperature of the slag, so I knew approximately what it was; this, with the blast temperature and the fixed carbon in the charcoal per pound of iron, supplied the necessary data for the calculation, which showed 1300 B.t.u. of hearth heat developed per pound of iron, while that developed in coke practice at the Isabella furnaces was only about 1000 B.t.u.

This astonishing result was the more remarkable because about 1200 lb. of slag per ton of iron were made in the coke practice and only about 500 in the charcoal. This could only be interpreted in one way, that more hearth heat was being developed than the furnace needed, and the excess was passing up into the shaft of the furnace and finding utilization there, but only in doing relatively low-temperature work. This in turn could only mean that the heat developed in the shaft was deficient in comparison with the hearth heat, and that if means could be found to increase the shaft heat the increase would prepare for final smelting in the hearth a greater proportion of ore, of which the excess of hearth heat could take care, so that the burden could be increased and the fuel consumption reduced, and incidentally, as we shall later see, the quality of the iron improved.

The ore used was a clayey Gogebic ore carrying normally 13-14 per cent of moisture, and a preliminary calculation showed that the abstraction of the heat required to evaporate this moisture from the small volume of gas which a charcoal furnace produces must lower the temperature of the gas about 400 deg., and as it was being discharged at about 200 deg. Fahr. it seemed as though the gas temperature would be high enough to do considerably more reduction, especially as the gas was amply rich for this purpose, if it did not have to drive off this water.

This seemed then to be a case in which the fuel economy of the furnace was controlled exclusively by the shaft heat developed per pound of fuel, the hearth heat playing a purely secondary rôle.

In order to ascertain whether this could be true detailed calculations were made covering the operation of the furnace as it was running and as it was believed it could run with dry ore. A similar set of calculations was then made covering the operation of a coke furnace which had made an excellent run to see how the existing and assumed charcoal cases compared with it.

The results of the whole investigation, which covered several months of laboratory work and all my time which could be spared from other work for three months or more, were embodied in a report to the executive of the company.

The major portion of this report is given here, as it covers the situation better than can be done in any other way.

THE EFFECT OF WET ORE ON CHARCOAL-FURNACE PRACTICE

"The conception that the great quantity of moisture present in the soft ores used in the charcoal practice of this district might affect the working of the furnace by undue cooling of the top gradually took shape in my mind from observing the top temperatures at a time when our fuel consumption was high.

"According to all previous experience high fuel goes with a high top temperature, but last fall when we were having fuel consumptions of 95 to 100 bushels our top temperature was down around 200 to 250 deg.

"A brief calculation based on the volume of gas and the quantity of moisture in the ore showed that the heat required to evaporate the water was sufficient to lower the temperature of the gas 300 to 400 deg. We had also found, by a good many analyses, that our top gases were as rich in CO as those of a coke furnace, although burning as we do much less fuel per ton of iron than in coke practice this should not be the case. An analysis

of the conditions was begun, based on three considerations:

"1. The ability of the gas to carry off all the oxygen of the ore with a given fuel consumption. This depends on the extent to which CO can be oxidized to CO_2 in the presence of iron ore at different temperatures.

"2. The total amount of heat developed in the furnace by the oxidation of the fuel to the extent at which it passes out in the top gases.

"3. The development of a sufficient amount of heat in the hearth to carry on the reactions which can only take place above the temperature at which the cinder runs freely.

"The importance of this last point rises from the following consideration: The fuel, say at the free-running temperature of the cinder, is burned by the blast at its incoming temperature with the development of a certain amount of heat, which, in the absence of burden, would heat the gases to a temperature known as the theoretical combustion temperature. When the burden is present, these gases are cooled down by it and give out their heat as they cool, but it is obvious that they cannot supply any heat at or above the free-running temperature of the slag (known as the critical temperature) after they are cooled down to that temperature. The amount of heat which they give out in cooling from the theoretical combustion temperature to the critical temperature may therefore be called the hearth or high-temperature heat. In coke practice the amount of this heat developed is generally smaller proportionately to the needs of the furnace than the total heat developed, and, consequently, it is the amount of this heat available which limits the fuel economy of a coke furnace. But in charcoal practice the critical temperature, that is, the free-running temperature of the slag, is so much lower than that of coke furnaces that the range from theoretical combustion temperature to critical temperature is much greater, and, therefore, the amount of hearth heat developed per pound of carbon is much higher, and it has been found by calculating the amount of high temperature heat developed per hundred pounds of iron in good coke practice, and the amount developed in our practice, that the latter was considerably *higher* than the former, although the slag volume to be melted and other work to be done in the hearth is much lower in our case.

"This indicated to my mind that we were developing more hearth heat than we needed, and making our iron hotter and of poorer quality in consequence, and I thought at that time that we should have some way of increasing the oxidation of the top gases so that we could increase the amount of heat in the upper part of the furnace, which, for lack of a better term, I call the shaft heat—shaft being the only name I know of for the portion of the furnace from the bosh to the top.

"After I had made the calculation showing how much the temperature of the gas was lowered by having to evaporate the moisture in the ore, it seemed to me that if the ore were thoroughly dried the top temperature would go up so much that the gases would be oxidized a good deal further, which would develop more heat per pound of carbon in the shaft, and as we had a surplus in the hearth this would enable more burden to be carried.

"In order to make reasonably accurate calculations, it was necessary to investigate along three lines as a preliminary: (1) the free-running temperature of the cinder; (2) the exact composition of the charcoal; (3) the extent to which the CO could be oxidized in the presence of iron ore at given temperatures.

"1. We have been carrying on, to the best of our ability, investigations of temperature of the running iron and cinder for over two years, and while they have not been completely satisfactory, they seem to indicate a temperature of 2300 deg. Fahr. as that at which a normal charcoal slag will run sufficiently freely for the furnace to work. Similar observations on coke furnaces several years ago indicated a temperature of about 2700 deg. Fahr. as that of a good slag in Bessemer practice.

"2. The composition of the charcoal. This was a matter on which we had made experiments in the past, but they were not successful enough to be considered reliable. We, therefore, put a piece of charcoal in an alundum boat in a silica tube heated by an electric furnace, surrounded it with an atmosphere of CO and heated it until no more gas came off. The gas was caught in rubber bags, its volume measured and its analysis obtained. The volume of CO used to fill the furnace was deducted from the total volume and the analysis of the gas was figured back to what it would have been if the CO had not been added in advance. Such a determination was made for birch and one for maple. The results checked exceedingly closely. As a further check the specific gravity of the gas was taken by weighing a small gas bag full of it, and this was compared with the specific gravity calculated from its analysis. The check was excellent. The charcoal remaining was weighed and then burned. The weight as taken from the electric furnace less the weight of the ash was considered to be the fixed carbon of the coal. From the analysis and volume of the gas evolved the weight of each gaseous component was figured and these were reduced to percentages by weight of the original sample of charcoal. The variations between birch and maple were very slight, and were averaged to obtain the figures given in Table IV.

Table IV.—Average Charcoal Analysis for Birch and Maple

	Per Cent
CO_2	4.50
O_2	0.67
CO	11.10
H_2	1.65
CH_4	3.40
N_2	7.77
Fixed carbon	68.50
Ash	1.00

"3. The extent to which the CO could be oxidized in the presence of iron ore at given temperatures. After overcoming the worst of the difficulties in this determination, we were unable from lack of time to get a long series of these determinations at different temperatures, as we had hoped, but we demonstrated by several runs that at a temperature of about 700 deg. Fahr. 62 per cent of CO_2 were in equilibrium with 38 per cent of CO. This means that if sufficient time were allowed it would be possible to oxidize the top gases so that the CO_2 would hold this ratio to the CO at this temperature. We also proved conclusively that the equilibrium percentage was much higher in CO_2 as the temperature arose. At 800 deg. it is about 70 per cent to 75 per cent, and at about 900 deg. it is around 80 per cent CO_2, but these figures are not exact.

"These were the data on which our calculations had to be based. It was decided first to take the conditions which prevailed with this furnace at the time these calculations were started. Ninety-five bushels of coal, 50 per cent ore yield, 13.50 per cent moisture in the ore, 400 lb. of limestone per ton of iron. From the tonnage made and the revolutions of the blowing engine the amount of blast per hundred pounds of iron was obtained, and by temperature observations of the air going into the cylinder and coming out it was possible to get a rough check on the displacement of the air cylinder. All gas volumes are reduced to 30 in. barom-

eter and 32 deg. Fahr. The specific volumes of gas are those given in Kent, and heats of combustion are taken from the same source, but the specific heats of the different components in the operation are taken from Richard's "Metallurgical Calculations." The specific heats given in Kent are not exact for high temperatures.

"It is necessary to call attention to one fact of much importance. The charcoal gas contains appreciable quantities of hydrogen and methane. Hydrogen requires for its combustion eight times its weight of oxygen, and methane for combustion to water and CO_2 requires four times its weight of oxygen. These are both very active reducing agents and will take up oxygen from the ore with great rapidity at a reasonably high temperature, 600 to 800 deg., but with the conditions under which the furnace works the top temperature is so low that they pass off largely without action on the ore. Our analyses have repeatedly proven them to be present in top gases. The quantity of oxygen which they can absorb is so great that the question whether they are oxidized completely or not affects the composition of the top gas tremendously.

"I have assumed that in a furnace using wet ore and 95 bushels of coal three-fourths of the hydrogen was burned and none of the methane, because this gives results which check out well with the actual gas analyses we obtained from the furnace, but, unfortunately, we did not get any during the exact period covered by the above assumption. However, the analysis of the gas in both CO_2 and CO, as well as in hydrogen and methane, is so close to what we actually found that no material error can be introduced into the heat calculations by any inaccuracy in these assumptions.

"A further fact is that the heat developed by combustion of CO and that developed by hydrogen per pound of oxygen consumed is nearly the same. Therefore, it is a matter of slight importance in regard to the development of heat whether the oxygen to be disposed of is consumed by hydrogen or by CO.

"Having made the calculation for 95 bushels of coal, I then made an exactly similar one assuming 75 bushels of coal with the ore thoroughly dried, and in this calculation I assumed that the gases would pass off at 400 deg. higher temperature than in the other, 632 deg. as against 232 deg., assumed as a fair average of the actual temperatures for 95 bushels with wet ore. This assumption was made because of the fact before mentioned that the amount of moisture present in the ore is sufficient to cool down the gases about 400 deg. In this case I assumed that the hydrogen and methane were completely oxidized because previous investigation on a furnace with a moderately warm top had shown this to be the case.

"In order to get some comparative figures from another source, I have made a similar analysis of the run of a coke furnace described by A. K. Reese, in Vol. 27 of the *Transactions* of the American Institute of Mining Engineers. This was a six months' run on the furnace at Canal Dover, Ohio. In order to check out the quantity of wind blown with the gas analysis given, it was necessary to assume that the volatile matter in the coke in this latter case consisted of methane and hydrogen, and that these were oxidized in the top of the furnace, as above described.

"Before proceeding to discussion of the results obtained in the three cases, it will be well to point out that the method of calculation of the total heat developed in the furnace is the time-tried and accepted one. The method of calculating the heat in the hearth has been used for the last seven or eight years, and has proven itself so reliable in giving relative figures in comparative cases that it is now generally accepted. See METALLURGICAL AND CHEMICAL ENGINEERING, March, 1913, page 147-8, "The Gayley Dry Blast," by H. M. Howe.

"In regard to the degree of oxidation of the gases in any given case, it is not commonly realized that this can be figured with considerable accuracy. The amount of blast blown supplies a given quantity of oxygen and the ore charged supplies another quantity. A slight additional amount comes from the gas given off by the charcoal, and a somewhat larger amount from the CO_2 of the limestone. All these have to come out of the stack, combined with the carbon which goes in in the form of fuel and in the form of CO_2 in the limestone, except for that which comes out combined with the hydrogen of the fuel. This, of course, is in the form of water and disappears in the gas analysis.

"As we know, with considerable accuracy, all of these weights of carbon, and hydrogen, and of oxygen, the degree of oxidation of the products of combustion can be accurately calculated and the heat developed determined with corresponding accuracy.

"All of the ores in this district are hematites, and therefore each seventy units of iron contain thirty units of oxygen, and the oxygen combined with the iron can be accurately figured from this. To this must be added the oxygen which comes from the silicon going into the iron, and due account must be taken of the fact that iron contains only about ninety-five units of Fe. I have assumed about 1.00 per cent to 1.25 per cent silicon, and have neglected the manganese in all cases, as the amount of oxygen accompanying it is too small in proportion to the possible variations in the larger quantities to be given serious consideration. This gives 42 lb. of oxygen released from the ore and silica per hundred pounds of iron. (It is very desirable to have a symbol which shall represent pig iron as distinguished from chemically pure iron, Fe, and for this purpose I have used the letter "I," because iodine does not enter into the discussion and no confusion can result.)

"The volume of blast blown was estimated from the displacement of the blowing cylinder, some allowances being made for the suction in the cylinder when the valves close and for the re-expansion of the compressed air into the clearance space, both of which tend to reduce the actual pounds of air blown. The temperature of the air being discharged from the cylinder was taken at the discharge head, and simultaneously that of the outside air, with which the engine was supplied. The heating of the discharge air was about 20 deg. higher than the theoretical for the pressure blown at the time, 6 lb., and this was assumed to take place before compression began and to make a further reduction of the weight of air delivered. The weight of air blown, derived from the displacement, with these corrections and with slight allowances for the loss in changing stoves and leakage, was used in the gas calculations, and checked out very satisfactorily with the actual analysis of top gas found. It may be well to remark here in passing that if incorrect assumptions be made, the calculated top gas will vary widely from the actual top gas analysis, and will at once indicate that something is wrong.

"It will be noticed that in the tables the weight of fixed carbon in the fuel per hundred pound of iron is given, and from this is made a deduction of 4 lb. to correspond with the 3.50 per cent or 4.00 per cent of carbon combined with the iron and some slight loss of solid carbon at cast and at flush time.

"The result of the calculations are each represented on a separate table, Tables V, VI and VII, in which it has been attempted to epitomize the calculation and to indicate the various reactions that lead to the top gas as finally discharged. In a general way the table gives,

FIG. 5

COKE PRACTICE

1667 lbs., of Coke Per Ton of Iron
(Canal Dover, Ohio, 1897)

HEARTH and BOSH — SHAFT

COMPONENT	Line Nos.	SOURCE	In Hearth and Bosh	Product	Disposal	Temp. at Ent'nce	Heat per lb. at Temp. of Ent'nce	Heat Brot to Hearth per 100 lb. Iron	Heat Comb per lb.	Heat of Comb per 100 lb. Iron	Total Heat in Hearth	Temp. at Exit	Heat per lb. at Temp Exit	Heat Taken Out of Hearth B.t.u.	At Top of Bosh per 100 lb. Iron	Released in Shaft	Before Re-Action	Re-Action	Product in Top Gas Lbs N	CO	CO2	H2	CH4	H2O	Gas Total	Heat from 32 to 432 per lb.	Heat Car out Top	Heat of Comb per lb.	Heat Comb per 100 lb. Iron	Heat Brot in at 2700	Total Hts. in Sh'ft	Cu. Ft.	Vol. of Top Gas
		Column Letters	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE
O	1	From Blast	70.			1100°	238.5	18200			18200																						
C	2	Burnt by O from Blast	57.						4450	253800	253800																						
	3	C O Produced		133.								2700°	728.	96880																		
	4	C for L & lost in Hearth	4.																													
	5	Total of C used in Hearth	61.			2700°	1120.	68300			68300																						
	6	Total fixed C in Furnace	61.																													
	7	C burnt in Shaft with O from Ore	—																													
	8	C O Produced	—																													
N	9	N from Blast	254.5												254.5																	
	10	N from Fuel																														
	11	Total N	254.5			1100°	272.	69260			69200	2700°	725.	184600					254.5						254.5	98.3	25000			184600	184600	32.50	63.7
H2	12	H2 from Fuel														0.55																
	13	H2 Burnt														0.55												61500	33800		33800		
	14	O for H2 Burnt															4.4															
	15	H2O produced																						4.95								
	16	H2 remaining																				—			—							
CH4	17	CH4 from Fuel														2.2												23500	49500		49500		
	18	O for CH4 to H2O + CO2															8.80															
	19	Product CO2																			6.05											
H2O	20	H2O Produced																						4.95								
	21	H2O from Ore																						10.80								
	22	Total H2O																							20.70	1260	26560						
O	23	O from Fe + Si														42.0																
	24	O from Fuel														—																
	25	Total O							•								42.0															
	26	Deduct O for CH4 + H2 Lines 18 & 14															13.2															
	27	Deduct O for fixed C not burnt by Blast															—															
	28	Net O for CO															28.8															
CO	29	CO from fixed C													133.															96800	96800		
	30	CO from fuel gas														—																
	31	Total CO															133.0															
	32	CO oxydized by net O, Line 28															50.4												4350	219200	219200		
	33	CO remaining															82.6			82.6					82.6	98.6	8140					1055	20.7
CO2	34	CO2 from CO + O																			79.2											
	35	CO2 from Fuel gas																														
	36	CO2 from Stone																			12.8											
	37	Total CO2																			98.05				98.05	87.0	8525					795	16.6

Total 409500
Removed by CO + N 281400
" " Dissoc H2O in Blast 9300
" " H2 from " " " 1800
" Total 292500
Net Heat used in Hearth 117000

281400

Total 68300 583900
Heat Removed by Top Gases 68300
Net Heat used in Shaft 515600

FIG. 6

CHARCOAL PRACTICE

HEARTH and BOSH — Wet Ore, Actual Case — 93 Bushels Coal, Per Ton Iron — SHAFT

COMPONENT	Line Nos.	SOURCE	In Hearth and Bosh	Product	Disposal	Temp. at Ent'nce	Heat per lb. at Temp. of Ent'nce	Heat Brot to Hearth per 100 lb. Iron	Heat Comb per lb.	Heat of Comb per 100 lb. Iron	Total Heat in Hearth	Temp. at Exit	Heat per lb. at Temp. Exit	Heat Taken Out of Hearth B.t.u.	At Top of Bosh per 100 lb. Iron	Released in Shaft	Before Re-action	Re-action	Product in Top Gas Lbs. N	CO	CO_2	H_2	CH_4	H_2O	Gas Totals	Heat from 32 to 232° per lb.	Heat Car out Top	Heat of Comb per lb.	Heat Comb per 100 lb. Iron	Heat Brot in at 2300°	Total Hts in Sh'ft	Cu. Ft.	Vol % of Top Gas
		Column Letters	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE
O	1	From Blast	62.1			1000°	212.	13200			13200																						
	2	Burnt by O from Blast	46.6						4450	207000	207000																						
C	3	C O Produced		108.7								2300°	608.	66200																		
	4	C for l & lost in Hearth	4.																														
	5	Total of C used in Hearth	50.6			2300°	922.	46000			46000																						
	6	Total Fixed C in Furnace	58.1																														
	7	C burut in shaft with O from Ore	7.5																														
	8	C O produced		17.5																													
N	9	N from Blast	207.9			1000°	243.5	50000			50000	2300°	600.	125700	207.9																125700	125700		
	10	N from Fuel														0.6																	
	11	Total N															214.5	→	214.5						214.5	47.2	10100					2740	58.8
H2	12	H2 from Fuel														1.4																	
	13	H2 Burnt														1.05												01500	64000		64000		
	14	O for H2 Burnt															8.4																
	15	H2O produced																→						9.45									
	16	H2 remaining														0.35						0.35			.35	.000	200					62	1.3
CH4	17	CH4 from fuel														2.89		→					2.89		2.89	82.5	240					65	1.4
	18	O for CH4 to H2O + CO2															—																
	19	Product CO2															—				—												
	20	H2O produced																						—									
H2O	21	H2O from Ore																						27.0									
	22	Total H2O																							30.45	1100	42300						
O	23	O from Fe + Si														42.																	
	24	O from Fuel														.57																	
	25	Total O															42.57																
	26	Deduct O for CH4 + H2 Lines 18 & 19															8.4																
	27	Deduct O for fixed C not burnt by blast															10.0																
	28	Net C for CO															24.17																
CO	29	CO from fixed C													108.7	17.5														60200	66200		
	30	CO from fuel gas														9.3																	
	31	Total CO															135.5																
	32	CO oxydized by net O, Line 28															42.3												4350	183000		183000		
	33	CO remaining															93.2			93.2					93.2	47.3						1193	25.5
CO_2	34	CO2 from CO + O																→			60.5						4000						
	35	CO2 from fuel gas																			3.8												
	36	CO2 from stone																			8.0												
	37	Total CO2																			78.3				78.3	40.5	3170					035	13.5
							Heat Removed by CO + N				317400			101900											425.7	00010				440409	4095		
							Net Heat Used in Hearth				101900														36.45	Heat Removed by Top Gases				60000			
											125500														389.2	Net Heat Used in Shaft				370800			

FIG. 7

CHARCOAL PRACTICE

HEARTH and BOSH — Dry Ore, 75 Bushels of Coal, Per Ton of Iron. Estimated Results — SHAFT

COMPONENT	Line Nos.	SOURCE	In Hearth and Bosh	Product	Disposal	Temp. at Ent'nce	Heat per lb. at Temp. of Ent'nce	Heat Brot to Hearth per 100 lb. Iron	Heat Comb per lb.	Heat of Comb per 100 lb. Iron	Total Heat in Hearth	Temp. at Exit	Heat per lb. at Temp. Exit	Heat Taken Out of Hearth B.t.u.	At top of Bosh per 100 lb. Iron	Released in Shaft	Before Re-Action	Re-Action	Product in Top Gas Lbs. N	CO	CO2	H2	CH4	H2O	Gas Totals	Heat from 32 to 632° per lb.	Heat Car out Top	Heat of Comb per lb.	Heat Comb per 100 lb. Iron	Heat Brot in at 2300°	Total Hts in Sh'ft	Cu. Ft.	Vol % of Top Gas
O			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE
	1	From Blast	56.			1000°	212.	11900			11900																						
	2	Burnt by O from Blast	42.						4450	186800	186800																						
	3	C O produced		98.0								2360°	008.0	59000																		
	4	C for 1 & lost in Hearth	4.																														
	5	Total of C used in Hearth	46.			2300°	922.	42400			42400																						
C	6	Total Fixed C in Furnace	46.																														
	7	C burnt in shaft with O from Ore	—																														
	8	C O Produced		—																													
	9	N from Blast	187.5			1000°	243.5	45000			45000	2300°	600.	113000	187.5															113000	113000		
N	10	N from Fuel														5.2																	
	11	Total N															102.7	→	102.7						102.7	149.	28700					2460	62.3
	12	H2 from Fuel														1.1																	
	13	H2 burnt														1.1												61500	67700		67700		
H2	14	O for H2 Burnt															8.8																
	15	H2O produced																						9.9									
	16	H2 remaining														—						—			—								
	17	CH4 from Fuel														2.3									—					54100		
CH4	18	O for CH4 to H2O + CO2															9.2																
	19	Product CO2																			0.33												
	20	H2O produced																						5.17									
H2O	21	H2O from Ore																						—									
	22	Total H2O																							15.1	1380	20800						
	23	O from Fe + Si														42.																	
	24	O from Fuel														0.44																	
	25	Total O															42.44																
O	26	Deduct O for CH4 + H2, Lines 18 & 14															18.00																
	27	Deduct O for fixed C not burnt by Blast															—																
	28	Net C for CO															24.44																
	29	CO from fixed C													98.															59000	59000		
	30	CO from Fuel Gas														7.4																	
CO	31	Total CO															105.4																
	32	CO oxydized by net O, Line 28															42.8												4350	186000		186000		
	33	CO remaining															62.6	→		62.6					62.6								
	34	CO2 from CO + O																			67.2					149.5	9400					802	20.4
CO2	35	CO2 from Fuel Gas																			3.												
	36	CO2 from stone																			8.												
	37	Total CO2																			84.5				84.5	136.	11500					085	17.3
								Heat Removed by		CO + N	230700			173200													70400				181000	3947	
								Net Heat Used in		Hearth	113500																Heat Removed by Top Gas Net Heat Used in Shaft				70100 111200		

in its upper left-hand corner, the details of what goes on in the hearth and bosh, and works gradually toward the final result in gas composition and heat development at the right-hand end and bottom of the table. It is feared that these charts may not be perfectly comprehensible at first glance, but no effort has been spared to make them as logical and clear as possible, so as to save the reader an enormous amount of effort in going over written details of these calculations.

"Coming now to the final results in heat development, we find that Table V, giving the actual conditions with wet ore, shows a development of hearth heat of 125,500 B.t.u. and a development of shaft heat of 379,800 B.t.u., a total per pound of iron of 505,300 B.t.u.

"The coke furnace in which, by the way, the theoretical gas analysis checks remarkably well with the actual results, shows a development of hearth heat of 117,000 B.t.u. and of shaft heat of 515,600 B.t.u., a total of 632,600 B.t.u. The assumed case, Table VII, dry ore and 75 bushels of coal, shows a development of hearth heat of 113,500 B.t.u., of shaft heat of 411,200 B.t.u., a total of 524,700 B.t.u. These are arranged in condensed tabular form below:

	Coke Practice, 1664 Lb. Coke	Actual Practice, Wet Ore, 95 Bu. Coal	Assumed Case, Dry Ore, 75 Bu. Coal
Hearth heat	117,000 B.t.u.	125,500 B.t.u.	113,500 B.t.u.
Shaft heat	515,600 B.t.u.	379,800 B.t.u.	411,200 B.t.u.
Total heat	632,600 B.t.u.	505,300 B.t.u.	524,700 B.t.u.

"Before proceeding to a discussion of these figures, it should be stated that in the case of the coke furnace it was assumed that the air blown contained four-tenths of a pound of moisture per thousand cubic feet of air, all of which moisture was dissociated in the hearth with corresponding absorption of heat. Further, that the hydrogen evolved by the dissociation of the water passed out of the top of the bosh at the same temperature as the other gases and abstracted a corresponding amount of heat from the hearth. The dissociation absorbs 9300 thermal units and the hydrogen absorbs 1800, a total of 11,100 thermal units. This assumption as to the amount of moisture present is based on previous experience of the moisture in engine houses during the winter months. It is not possible that the air was taken from outside the engine room, as no mention is made of that fact and it was not customary at that time (1879).

"To be strictly accurate, allowance for the oxygen from this source should be made in the gas calculations, and as the hydrogen generally recombines in the top of the furnace with oxygen from the ore, the 11,100 thermal units subtracted from the hearth heat might, with propriety, be added to the shaft heat. These corrections have not been made because their magnitude is not of sufficient importance to affect the general result, and they would greatly complicate the tables to show them. No allowance for moisture is made for our practice, because we take our air from out of doors and the amount of moisture present in the air in winter time in this climate is a negligible quantity.

"Comparing first the two actual cases, coke and 95 bushels of charcoal, we see that the heat developed in the hearth with the charcoal is considerably greater, while the heat developed in the shaft is very much less than with coke. The difference in the latter condition of over 100,000 thermal units is very striking. The explanation of the major part of the difference lies in higher temperature to which the materials must be heated in the shaft of the coke furnace than in the charcoal, and also the much greater amount of limestone to be decarbonated in the coke than in the charcoal. Only approximate calculations are possible on this subject for lack of accurate data as to specific heats of the materials at these high temperatures, but such calculations indicate that most of the difference can readily be accounted for in this way.

"Turning now to the high temperature, or hearth heat, the conditions are extraordinary. The coke furnace, with a considerably greater quantity of slag, greater radiation losses and every disadvantage compared with a charcoal furnace, develops about 7 per cent less high-temperature heat than the charcoal furnace. Moreover, an examination of the table will show that while 58 lb. of fixed carbon are brought into the furnace by the charcoal, only about 50 lb. are consumed in the hearth—4 by absorption in the iron and 46 by combustion with the blast. This shows that about 8 lb. out of 58, or 14 per cent, of the total fixed carbon are dissolved by the oxygen of the ore. If this carbon came down into the hearth as it should, the excess of high-temperature heat for the charcoal furnace would be very much greater than it is.

"It seems well to point out here one curious fact. When CO is oxidized to CO_2 by oxygen taken from the ore, heat is given out by the reaction; but when carbon is burnt to CO by oxygen from the ore, an enormous amount of heat is *absorbed* for every pound of oxygen which is transferred from the ore to the carbon. This is because a unit of oxygen develops over twice as much heat in burning CO to CO_2 as it does in burning C to CO. Knowing the amount of carbon which is thus burnt directly, we can easily figure the heat absorbed. This amounts to 33,000 thermal units per 100 lb. of iron. We do not know where this reaction takes place, but the action of this furnace and the frequent observation of forge cinder at or below the level of the tuyeres when the furnace is in normal operation causes the belief that a great portion of this combustion of fixed carbon with oxygen from the ore takes place in the hearth itself, and thereby robs the hearth of the excess heat which it develops.

"Extensive investigations have been made in Germany on the equilibrium between FeO and Fe_3O_4 with CO and CO_2. These investigations proved that at temperatures of 1800 deg. to 2000 deg. CO could contain a considerable percentage of CO_2 and still deprive FeO of all its oxygen; but if the temperature went higher than this the affinity of the iron for oxygen increased so much that pure CO or incandescent carbon would be required to deoxidize it completely. This means that at the top of the bosh where the combustion of the blast to CO is complete the temperature should not be too high, as high temperature prevents complete deoxidation by the CO, and requires the use of solid carbon for that purpose, with consequent waste of fuel. Thus it may actually be that excess fuel leading to high temperature in the hearth exercises an unfavorable action on the final reduction of the ore.

"It is perfectly obvious that the effect of wet ore on gas is to cool it down with extreme rapidity as it approaches the top of the furnace, and while the physical heat thus lost is of some importance, a condition of vastly greater importance results from it. This is that the temperature of the gas is so far reduced that it can no longer react on the ore. This means that oxygen which should be removed from the ore near the top of the furnace with decided evolution of heat descends to lower levels, and that which should be reduced in the central zone descends to or above the top of the bosh before it is finally removed. This involves the reaction with solid carbon, above pointed out, and the destruction of fuel economy.

"The effect of the excess heat in the hearth I believe to be bad also for the quality of the iron, because in the region around the tuyeres the temperature developed is excessive, this temperature being given up by the

gas to the stock in a slightly higher zone, in order to overcome the cooling effect produced through the direct reaction of the oxygen of the ore by the incandescent fuel. These high temperatures at the tuyeres tend strongly to superheat the iron as it drips down through this zone. This increases its affinity for carbon, which the presence of an excess quantity of carbon permits it to satisfy. Therefore, the tendency of this working is to produce a hot-made high-carbon iron, although the silicon may not be high, due to the scouring action of the oxide which comes down to, or nearly to, the zone of the tuyeres.

"Turning now to the assumed case of correct top conditions and a fuel consumption of 75 bushels of coal, we find that the heat developed in the hearth is the same, or virtually the same, as that in the coke furnace (although the requirements as above pointed out are not so great), while the heat developed in the shaft of the furnace is very materially greater than with 95 bushels of coal and wet ore, about 407,000 thermal units against 378,000.

"The critical point in this assumption is the ratio of the top gases. It will be seen that this works out to 17 per cent of CO_2 and 20.3 per cent of CO, as compared with the actual results in the coke furnace of 15.6 per cent of CO_2 and 20.7 per cent of CO, a ratio of 0.75 : 1 for the coke furnace to 0.84 : 1 for the assumed charcoal conditions. This is not a very much higher ratio of CO_2, and is far lower than the equilibrium ratio, which is 1.63 : 1; that is, 62 CO_2 to 38 CO. In other words, it is possible for ore to oxidize the carbon gas to a very much higher degree than would be required for 75 bushels of coal under the given conditions.

"In regard to the time allowed for this reaction, it is well to note that the volume of the furnace in proportion to the volume of gas passing through it is very much greater in the charcoal furnace than in the coke one, which allows a correspondingly longer time for reaction.

"The development of more heat in the shaft of the furnace with over 20 per cent less fuel than in the actual case may appear to indicate erroneous figures, but this is not the case if we admit the possibility of the degree of oxidation just explained. The amount of oxygen from the ore for a hundred pounds of iron is virtually constant. For the same analysis of iron and same kind of ore it is exactly constant.

"This constant quantity of oxygen would oxidize the same quantity of CO to CO_2 in either case and develop the same amount of heat in doing so if all the fixed carbon were burnt to CO by the blast, but the smaller the quantity of fuel burned in the hearth per pound of iron, the greater the proportion of this which is oxidized to CO_2, and therefore the greater development of heat per pound of fuel. Moreover, in cases where all the carbon is not burnt to CO in the hearth by the blast (the case of wet ore, for instance), a part of this oxygen from the ore expended in burning C to CO, which, as explained above, generates less than one-half the heat per pound of oxygen consumed that is generated by the oxidation of CO to CO_2, hence not only a less proportion of the total CO is oxidized in the case of the larger fuel consumption, but the total supply of oxygen available for this purpose is reduced about one-fourth to satisfy the fixed carbon of the fuel, hence only three-fourths as much is available for oxidation of CO to CO_2 as in the case of smaller fuel consumption. Thus not only the relative but also the absolute oxidation of CO to CO_2 is much smaller with the larger fuel consumption. This, of course, is only true within the limits of possible oxidation of carbon gas above described.

"It might be thought that this whole line of argument was fallacious because it was the hearth heat which limited the fuel economy, as it undoubtedly is in most coke practice. If this were so we could produce an enormous change in the burden-carrying capacity by changing the temperature of the blast. The heat brought in by the blast for 95 bushels of coal at 800 deg. is 50,000 thermal units, at 1000 deg., as given in the table, 63,700, and at 1200 deg. 78,700. The high-temperature heat being 124,800 B.t.u. for 1000 deg. blast temperature would become 111,100 for 800 deg. and 138,800 B.t.u. for 1200 deg.; therefore, raising or lowering the blast temperature 200 deg. would produce a difference of about 11 per cent either way, or there would be an economy with 1200 deg. of blast temperature over that at 800 deg. of about 24 per cent. As a matter of fact, the difference which we find in fuel consumption for such a change in blast temperature is about 5 per cent. This corresponds approximately to the difference in total heat supplied to the furnace in the two cases, which figures about 5.50 per cent.

"It may be taken as established, therefore, that the amount of hearth-heat produced is not the limiting condition in regular charcoal practice, but that this limitation comes from the amount of shaft heat developed per pound of carbon burnt. This depends, as already pointed out, on the degree to which the top gases can be oxidized by the ore, and this, in its turn, depends on the temperature of the gases. If they remain hot they will continue to react on the ore until they are discharged, but it would be as unreasonable to expect them to do this when chilled with water and diluted with steam as to expect a fire to burn as freely with a hose turned on it as without."

As a result of this investigation arrangements were made to dry 500 tons of ore for a trial run, and while this amount was sufficient for only two days the results bore out in the most striking manner the conclusions derived from the calculations. The fuel consumption was decreased about 12 per cent, and this threw the deficiency of heat into the hearth, with the result that the furnace responded to changes in blast temperature to an extent that was almost incredible, in view of previous experience, and everything indicated, as far as so short a trial could, the complete agreement of practice with this theory of two thermal equations instead of a single one, as in the older theory, and that both of these must be satisfied before the furnace would function, even though the satisfaction of one involved a great surplus of heat above the requirements for the other.

A second article on the thermal principles of the blast furnace will follow.

Electroplating with Cobalt.—The complete report on the work done on plating with cobalt by Dr. Herbert T. Kalmus, C. H. Harper and W. L. Savell has been issued by the Canadian Department of Mines as Bulletin No. 334. A description of this work was given in our issue of May, 1915.

The Mineral Resources of Texas, by William B. Phillips, is the title of Bulletin No. 365 of the University of Texas. The work is restricted to mineral products and undeveloped resources are not considered. It is a very complete account of the products of Texas and contains much valuable information.

Products and By-Products of Coal.—In Bulletin No. 323 of the Canadian Department of Mines, recently published, Messrs. Edgar Stansfield and F. E. Carter present a general outline of the products and by-products obtained from the utilization of fuels in Canada. The publication is of special interest in view of its connection with the dyestuff problem which has confronted Canada as well as the United States.

Potash from Wood and Plant Ashes

BY HARLOW BRADLEY

INTRODUCTION

Recently several companies have been formed for the extraction of potash from the enormous kelp beds along the Pacific Coast, but whether this method will be commercially successful or not remains to be seen.[1]

Considerable interest has been evinced, however, since the European war stopped imports from Germany, in the possibility of producing potash from wood ashes, and the present paper will attempt to deal with this phase of the subject.

HISTORICAL

The production of potassium carbonate, or potash, from wood ashes is one of the oldest of the purely chemical industries and was fairly extensive fifty years ago in Russia, the United States and Canada. Elm, birch, larch and maple were the woods most generally used, and the devastation of the forests in the vicinity of leaching plants was beginning to assume alarming proportions.

The rapid development of the well-known Stassfurt potash deposits after 1870, however, had an immediate effect on the production of potash from wood ashes. In twenty years the amount produced in this way was not even half of the world's production, as the figures for 1890, given in Table I, furnished by H. Grüneberg,[2] will show:

TABLE I—WORLD'S PRODUCTION OF POTASH IN 1890

	Tons
Wood ashes—Russia, Canada, United States, Hungary, Galicia	20,000
Beet sugar waste—France, Belgium, Germany	12,000
Mineral salts—Germany, France, England	15,000
Suint (wool scourings)—Germany, France, Belgium, Austria	1,000
World's production	48,000

"These conditions differ strikingly from those which existed thirty years ago (in 1860), when wood ash was in exclusive use, and Russia potash ruled the market."

The industry in America was slowly undermined until, at the present time, the amount of "pearl ash," or refined "potashes," made either in the United States or Canada, is insignificant. Ashes are still used for fertilizer to a small extent, and farmers often lixiviate them to produce a lye for soft soap; an industry still exists for making a commercial potash, but it is very small. Before the war practically all of our potash was coming from the Stassfurt mines, giving the German Kali Syndicate a virtual monopoly.

The Twelfth Census[3] gives some interesting figures on the extent of the potash industry in America fifteen years ago.

"Though returns for the census year 1900 were received from sixty-seven establishments, producing 3,864,766 lb. of potash, valued at $178,180, no pearl ash was reported manufactured. Of these sixty-seven establishments, twelve produced products valued at less than $500. Cognizance was taken of this industry in the reports of the United States as early as 1850, so that the data are at command for comparing the condition of the industry in this country for each decade since 1850, as set forth in Table II.

"This Table II shows that there was a constant decrease in the value of the product, though the quantity varied somewhat."

TABLE II—TOTAL PRODUCTION OF POTASHES, BY DECADES 1850 TO 1900

Year	Number of Establishments	Product: Pounds	Product: Dollars	Average Price per Pound Cents
1850	569		1,491,533	
1860	212		538,550	
1870	105		327,671	
1880	68	1,571,671	232,643	5 09
1890	75	5,106,939	197,507	3 86
1900	67	3,864,766	178,180	4 82

The establishments reported in 1900 were distributed as stated in Table III:

TABLE III—GEOGRAPHICAL DISTRIBUTION OF POTASH FACTORIES 1900

States	Number of Establishments	Average Number of Wage Earners	Capital	Value of Product	Per Cent of Total
United States	67		$70,899	$178,180	100 0
Michigan	44	52	25,851	79,642	44 7
Ohio	15	25	20,050	35,519	19 9
Indiana	3	4	2,275	6,560	3 7
Maine, Wisconsin, Illinois	5	11	22,723	56,459	31 7

"There were reported as having been used in this manufacture 812,399 bushels of wood ashes valued at $40,191. The yield of potash per bushel of ashes, as reported, varied from 2.4 to 7 lb. In the product given above there is included potash packed in cans, amounting to 820,000 lb., having a value of $53,349. Excluding this, as being in the nature of a duplication, it appears that the total production of potash for 1900 was 3,044,766 lb., and that, therefore, the average yield of potash per bushel of wood ashes, as shown by the extra returns, was 3.75 lb. Pelonze and Fremy[4] give the yield by weight as 10 per cent, and this appears in other textbooks; but all returns for ashes received at the census of 1900 were given in bushels.

"From the data for production given above it is evident that although the average price of potash for 1900 was higher than for 1890, the industry was not remunerative and consequently the total quantity and value of the product decreased.

"The cost of producing a barrel of 650 lb. of potash was stated by a Michigan manufacturer to be as given in Table IV:

TABLE IV

Ashes, 150 bushels, at 3c	$4.50
Hauling ashes	6.00
Fuel	2 00
Labor	3 00
Barrel, cost of	1.25
Repairs, interest, etc	1.50
Total	$18 25
Selling price at works	25 00
Gross profit, per bbl.	$6.75

"The ashes, therefore, yielded 4 1/3 lb. of potash per bushel, and the potash sold at 3.85 cents per pound. It will be noted that the weight of a barrel of potash is given above as 650 lb. From the returns it appears that the net weight of a barrel of this material varied from 650 to 740 lb., the average being about 700 lb."

USES OF POTASH

The chief use of potash is in the form of crude mineral salts for fertilizer purposes. Over $13,000,000 worth of these crude salts was imported in 1912. Large quantities of potassium in the form of the cyanide are used in the recovery of gold from tailings and low-grade

[1] See Bulletin No. 248, Univ. Cal. Agric. College: J. S. Bird, Economic Value of Pacific Coast Kelps.

[2] Wagner—Chemical Technology, 1892, p. 299.

[3] Twelfth Census of the United States, Vol. X—Part IV—pp. 543-546.

[4] Traité de Chemie, 1865—Vol. II, p. 225.

ores. The glass industries require potash for certain forms of glass, and some potash is used for the manufacture of soft soap. Previously most of the manufactured potassium salts were imported, but potash is now used in this country for the manufacture of the chromate, the hydrate (caustic potash) and several others.

MANUFACTURE OF POTASH FROM WOOD ASHES

Potash is prepared by dissolving out the soluble contents of wood ashes and evaporating the solution to dryness. The process as carried out formerly on a commercial scale is as follows:

The wood, often mixed with vine stalks and ferns, is incinerated in pits 3 or 4 ft. deep and sheltered from the wind. The material is thrown in in portions and burned until the pit is nearly full of ashes. The latter are then removed, spread on a floor and dampened. According to an old observation ash which has been stored a long time produces more potash. This is because the silicate of potassium is transformed to carbonate by the carbon dioxide and water in the air.

The ash should be spread in moderately thin layers and turned for several months. It is doubtful, however, whether the increased yield of potash pays for the large amount of floor space necessary. Should the silicate content of the ash be comparatively high, an artificial method could probably be introduced. Often (in American practice) a small amount of lime (5 per cent) is added.

The ash is now placed in tubs or vats, formed from tar barrels by cutting them in half. These are arranged in double rows, one above the other, to permit the weaker leachings to run from the upper vats to the lower. The vats are provided with two cross beams, which support a cullendered false bottom covered with straw, and below this is a cock for the removal of the lye. Water, preferably hot, is poured on the mass in the upper vats and emerges strong lye.

If it is 32 deg. Tw. strong (20 deg. Bé., 20 per cent to 25 per cent salt), it can be boiled down at once; the weaker liquors and washings, however, are run through several vats successively. Care should be taken to have the ash well tamped down in the vat. Using cold water would leave the potassium sulphate behind, but hot water is used to obtain more potash, and the sulphate can be separated out later. The latter is valuable to the manufacturers of alum.

The leached residue, which contains some potash and available phosphoric acid, makes a fair fertilizer. The lye is boiled down in shallow evaporating pans made of iron with corrugated bottoms to produce a greater heating surface. The boiling down is generally a rough process. The waste heat can be used to warm the feeder which supplies the pans. In lieu of pans possessing a large heating surface (pans fired from the top would be best), circular cast-iron pots are often employed.

Evaporation progresses rapidly at first and new supplies of strong liquor are poured in, the heat being continued until a sirupy consistence is attained, when the fire is gradually slackened, and the contents of the pan becoming solid (containing about 6 per cent moisture) are dug out and placed aside as crude potashes.

In spite of much stirring before the mass becomes quite dry, much of it burns fast to the pan, causing a great waste of fuel and a speedy destruction of the bottom.

In Russia the lye was concentrated in copper kettles to the point of crystallization and then discharged into wooden cisterns where potassium carbonate crystallized out. After draining, the carbonate was calcined and the mother liquor returned to the cistern.

In America the mass was heated nearly to redness and converted into greyish-pink compact potashes, which were assorted into firsts, seconds, thirds and unbrandables.

The brown crude potashes are calcined in a reverberatory furnace, which causes the carbonaceous and other organic matter to burn away, the hydrate being carbonated and the sulphide converted into sulphate. The loss in weight during this operation is from 10 to 20 per cent. Too great a heat is to be avoided because the mass would then fuse, leaving a mixture of fine charcoal, from the carbonaceous material, and salt which cannot be burned white.

Potassium carbonate is difficult of fusion, but when large amounts of chloride are present the mixture fuses at an incipient red heat. The resulting product is white with a bluish tinge, the latter due to small amounts of potassium permanganate, contains more carbonic acid than the crude product, and is called "pearlash." A purer material is obtained by dissolving this pearlash in water, separating the insoluble matter, evaporating the liquor, and calcining it again. This latter process was generally used in America.

The American practice used so much lime that the major portion of the potassium existed as hydrate. In this way some of the silicate, which would otherwise have been lost, was recovered as hydrate. Potash with a large quantity of lime in it must be even more carefully protected against attracting atmospheric moisture than ordinary commercial carbonate, although the latter is also deliquescent. Such semi-caustic potash was very much in demand by soap makers, as it took less lime to make their lye and caused less loss.

In purifying carbonate of potash either of two methods can be employed: The carbonate may be stirred up in an iron pot with 1½ or 2 times its weight of cold water, and the mixture, which gets hot, allowed to cool down before siphoning off the clear liquor. The sulphate and some chloride remain behind together with the insoluble matter; the residue is not washed (which would cause the sulphate to be redissolved), but only pressed. The liquor, containing mostly carbonate, but also chloride and silicate, is brought to dryness, stirring it up to the end.

The second method is to dissolve the material in hot water; the residue is exhausted in the same way. The liquors are boiled down to a specific gravity of 1.50 and allowed to cool, when the sulphate and some chloride crystallize out. This process is more expensive than the former.

In order to make still purer carbonate for flint glass, pearlashes are calcined with a little sawdust, lixiviated, and the clear liquor boiled down and calcined. This is repeated twice over, and the last product is dried down until it is converted into granular "crystallized" carbonate with 15 per cent to 18 per cent water (less deliquescent—$K_2CO_3 \cdot 2H_2O$).

Fig. 1 is a sketch of a typical calcining furnace. Air entering through *b* passes up through grate *a* and the flame plays over *t* upon the calcining hearth. The furnace should be warmed before charging and should be run continuously.

When the furnace is red hot 300 or 500 lb. of crude potash are broken up and spread over the calcining hearth. Water begins to come off, violently if too much is present, so that the heat must be raised gradually. It takes about one hour to drive off the moisture and constant agitation must be practised.

The heat is then increased to redness so that the combustible and coloring matter is consumed. At this period the potash takes fire, burning with a flame of slight intensity, becoming black from the carbonization

of the combustible material. It becomes clearer and clearer until at length a sample drawn off appears quite white. Some potash sticks to the hearth of the furnace, and the flame is allowed to play over it until it softens, when it can be removed. The white calcined ash is removed and allowed to cool, and should be packed in close casks before it has an opportunity to absorb moisture.

POSSIBLE IMPROVEMENTS IN THE METHOD OF MANUFACTURE

Assuming that a sufficient supply of wood ashes was available to supply a plant for operation at the present time, many improvements could be made in the leaching, evaporating and calcining apparatus over the old methods. Leaching vats with a greater capacity than the tar barrels, and provided with cullendered, metal, false bottoms and a more efficient filtering medium than

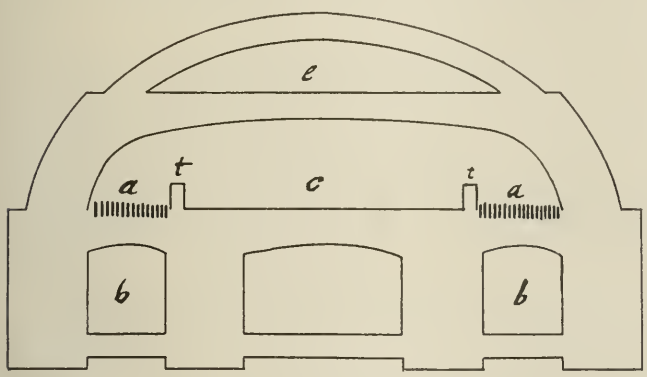


FIG. 1—CALCINING FURNACE

aa—grates. bb—ash pits. c—calcining hearth 3 to 4 ft. wide. tt—fire bridges, iron plates. e—not necessary, may be used for other purposes.

straw, could be arranged in batteries much after the fashion of beet sugar diffusion batteries. In place of the shallow evaporating pans, or the cast-iron pots, an evaporator of the Enderlein type provided with a rotary calcining furnace, could be used, such as is employed in the recovery of soda at the soda and sulphate pulp mills. Fuel being no object, since the ashes would be a source of potash, this arrangement could do without the vacuum evaporators used at pulp mills for the preliminary concentration of the weak spent liquor, thus saving a considerable investment. A brief description of the Enderlein evaporator follows.

This apparatus consists essentially of an open wrought-iron vessel about 16 ft. long, 7 ft. deep and 14 ft. wide, inclosed in a brick chamber. Two shafts, each mounted with thirty-two wrought-iron disks, 5 ft. 6 in. in diameter, set about 5 in. apart, run across the vessel. The shafts are mounted 7 ft. apart, center to center, and the disks are intended to dip into the liquor. About one-sixth of their surface is submerged in the lye, giving a total surface exposed to the hot gases of 3140 sq. ft. The shafts revolve at nine or ten revolutions per minute.

At the front of the evaporating chamber, and opening into it is the rotary calcining furnace or roaster. This is about 16 ft. long by 8 ft. in diameter, slightly inclined away from the evaporator, and revolves at a slow rate of speed dependent on the conditions of evaporation. The liquor, which runs continuously into the evaporator, runs out in concentrated form through a weir into the rotary roaster, where it is evaporated nearly to dryness, and drops out at the other end between the mouth of the roaster and the smelter.

The smelter as used at pulp mills is merely a firebrick lined chamber or dutch oven, but for recovering potash a calcining furnace of the hearth type might be used. As the black ash drops out at the end of the roaster it is shoveled into the calcining furnace where the organic matter burns, providing most of the heat for evaporation.

About 15,000 to 20,000 gallons of waste soda pulp liquor can be evaporated from 16 deg. Bé. to 37 deg. Bé. with this apparatus in twenty-four hours, or about 1.25 lb. of water per square foot of heating surface per hour. The operation of this apparatus would probably have to be modified somewhat in dealing with potash.

CHARACTERISTICS OF POTASH PRODUCED FROM WOOD ASHES

Calcined potash is a hard, light, porous, and granular saline mass—the white color merges into pearl grey or becomes yellowish or bluish. Single pieces often exhibit blue and red spots on the fractured surface. The red is caused by oxide of iron, grey by carbon particles, and blue by the action of the alkali on oxide of manganese, giving rise to small amounts of potassium permanganate. Insoluble matter in varying quantities is generally present in commercial potashes—partly due to imperfect filtration through the straw in the leaching vats and partly to ashes being carried over in the calcining furnace.

In the soluble portion potassium carbonate, potassium sulphate, potassium chloride, and potassium silicate are always present. Sodium carbonate, potassium phosphate, potassium bicarbonate, potassium hydrate, sulphide of potassium, manganate of potassium, and organic matter are sometimes present.

In the insoluble portion there is always silicic acid present, and sometimes silicate and phosphate of lime, calcium carbonate, magnesium carbonate, magnesium phosphate, oxide of iron, protoxide of manganese, alumina, and lastly sand and carbon.

The caustic potash present is due to the addition of slaked lime, as stated before, and is found only in American potash. Sulphide of potash is caused by the action of organic matters on the sulphate, while bicar-

TABLE V—ANALYSES OF COMMERCIAL POTASHES AND PEARLASHES, PRODUCED FROM WOOD

Origin	Quality	K_2CO_3 Per Cent	KOH Per Cent	Total Alkali Calc. as K_2CO_3	Total Potash Calc. as K_2CO_3	Na_2CO_3 Per Cent	K_2SO_4 Per Cent	KCl Per Cent	Analyst
American potash...	.....	68	.....	75 5	68	5.8	15.3	8 1	Pesier
American potash...	1	41.7	49.6	108.2	106 4	1.4	4 0	2.0	F. Mayer
American potash...	2	19.4	44.4	87.8	77 2	8 2	16 1	5 6	F. Mayer
American potash...	2	18.3	36.6	81.7	65 9	12.2	15 1	14 6	Grüneberg
American potash...	2	34.5	29.6	81.8	77.9	3 0	15 0	7 5	Grüneberg
Montreal potash....	Firsts	43.87	50.03	92.49	88 83	6 24	16 07	4 41	Tatlock
Montreal potash....	Firsts	26.16	36 50	89.82	85 54	2.84	10 40	1.68	Tatlock
Montreal potash....	Seconds	38.53	42.44	85.79	76.24	11.47	18 92	12.82	Tatlock
Montreal potash....	Seconds	21.71	30 63	85.08	73 98	8 52	9.18	6.13	Tatlock
Montreal potash....	Thirds	46.31	6.14	72.10	53 86	17 81	20.53	7.63	Tatlock
Canadian pearlash..	.....	71.3	.....	74.2	71.3	2 3	14.3	3.6	Pesier
Canadian pearlash..	.....	65.0	.....	70.2	65 0	4 0	21.0	7.0	Grüneberg
Canadian pearlash..	1	77.50	.....	80.98	77 50	2 86	11.65	2 65	Tatlock
Canadian pearlash..	.....	71 38	.....	74.53	71 38	2.31	14.38	3.64	Tatlock

bonate of potassium must be due to the action of carbon dioxide from the gases.

Table V shows the composition of various potashes produced in America.

THE PRACTICAL UTILIZATION OF ASHES

THE INORGANIC CONSTITUENTS OF PLANT AND WOOD ASHES

Plant ashes of all kinds, as well as wood ashes, contain varying quantities of potassium salts; in fact, many herbaceous plants contain much higher percentages of this material than trees do.

Sage brush (artemesia), for example, which grows in considerable quantity in the West, contains from 5 to 7 per cent of K_2O, based on the weight of the plant, or about 20 to 30 per cent on the weight of the ash.[5] The brush must be cleared from the land to enable plowing, and this is often done by dragging heavy railroad rails over the ground, the brush being collected in piles and burned. It would not be profitable to save the ashes for leaching in this case, although they can be thrown back on the land for fertilizer.

In this connection it might be well to note that when black sage is steam distilled, an oil is produced containing considerable camphor.[6] Should the distillation of this material prove commercially possible, the waste could be burned for its potash content. That the artemesias have been considered as a source of potash is shown by the following quotation from Knapp's Chemical Technology:

"Hermbstädt planned to plant wormwood (an artemesia) for the production of potash, as it grows on very poor soil. One Magdeburg acre (18,000 sq. ft.) affords in a summer three crops, or 20,000 lb. of the dry plant, which produces 2364 lb. of ash, or 936.6 lb. of potashes. The plan was forbidden by the German Government as wormwood takes the potash out faster than it is produced by disintegration of the soil."

This artemesia is not the same as our black sage, which is perennial and would require two or three years' growth between each harvesting.

In Java the stems and leaves of the indigo plant were used to produce potash after the extraction of the coloring matter, while the Russians produce a potash for soap making from the ash of the stalks, hulls and leaves of the sunflower.[7] About one-fifth of this should be thrown back on the land for fertilizer. The sunflower industry in Russia is a large one, the seed being pressed for its oil, or eaten as peanuts are in America.[8] Cottonseed hulls were burned extensively for fuel in the Southern States, and the ashes used for fertilizer or for making potash, but at present the hulls command a higher price as cattle food. An analysis of cottonseed hull ashes is given in Table X. The mangrove tree, growing in marshes where the water is soft, contains high percentages of potash, it is stated.

Potash occurs mainly in the stems and leaves of plants. The amount present varies greatly in different parts of the plant, and is dependent upon the season of the year and the nature of the soil. Two trees of the same species, growing side by side, generally show differences in the amount of potash taken up, so that the ashes found on the market were exceedingly variable in composition.

Tables VI and VII illustrate the above facts very well.

Bottinger showed that the soil may affect the constituents of the ash. A sickly fir tree growing in the neighborhood of a manganese mine contained 15 per cent of protoxide of manganese on the weight of the ash, while in healthy wood only 2.7 per cent was found. In a like manner, Saussure got 12 per cent ash from flowering vetch growing on arable land, while from the same plant grown in distilled water only 4 per cent was found.

Prof. E. Emmons, from 150 analyses of ashes of American woods, deduced the following:

1. Proportion of ash in limbs and branches greater than in inside wood, and greater also in outside than inside wood, though exceptions occur to latter inference.
2. Inorganic matter acquires maximum proportion in bark of trunk.
3. Alkalies acquire maximum proportion in fruits and envelopes.
4. Phosphates acquire maximum proportion in outside woods, fruits and envelopes.
5. Lime acquires maximum proportion in bark.
6. Phosphates and alkalies acquire maximum proportion in bark of trunk.

Table VI—Variability of Plant Ashes
Ashes of Fir from Different Localities (Saussure)

	1 Per Cent	2 Per Cent
Carbonate of potash	3.6	7.36
Carbonate of lime	46.34	51.19
Carbonate of magnesium	6.77	None

Table VII—Amount of Ash in Different Parts of Trees (Saussure)

	Per Cent Ash
Oak leaves, May 10	5.3
Oak leaves, September 27	5.5
Oak wood	0.2
Oak bark	6.0
Oak wood (branches—sapwood)	0.4

The character of the unleached wood ashes found in the trade is indicated in Table VIII,[9] showing the mean, maximum, and minimum results of the analysis of ninety-seven samples by Grossman.[10]

Table VIII—Mean Composition of Wood Ashes

	Mean, Per Cent	Maximima, Per Cent	Minima, Per Cent
Potash	5.5	10.2	2.5
Phos. acid	1.9	4.0	0.3
Lime	34.3	50.9	18.0
Magnesia	3.5	7.5	2.3
Insoluble	12.9	27.9	2.1
Moisture	12.0	28.6	0.7
CO_2 and undetermined	29.9	....	....

The potassium found in wood ashes is extracted from the soil by the plant during its growth, the presence of potassium compounds in the soil being essential to the growth of vegetation. Consequently, wood ashes are valuable fertilizing material. Ordinary soils contain from 3500 to 12,000 lb. of potash per acre to a depth of 1 ft.

The results of many analyses of plants and plant ashes, partly of European origin, are compiled in tabular form in Tables IX and X.

It is not intended that such materials as rye, straw, potato stems, thistle, and vine pith are to be considered as a practical source for potash. These analyses are merely included for the sake of completeness. The cost of collecting such materials or even their ashes would be prohibitive.

The potash in cottonseed hull ashes varied from 10 per cent to 42 per cent and the total phosphoric acid

[5] See U. S. Patent 896,168, Aug. 18, 1908.
[6] See Bulletin 235, Bureau of Plant Industry, U. S. Dept. of Agriculture.
[7] Chem. Tr. J., Aug. 12, 1911.
[8] Consular Report, No. 137—1892.
[9] Handbook of Experiment Station Work—A Digest. U. S. Dept. of Agriculture, 1893.
[10] Annual Report, Mass. Agric. Exp. Station, 1888—p. 202.

TABLE IX—ASH IN 100 PARTS—PLANTS

Potato stems	15.00 Berthier
Potato leaves	1.15 Mollerat
Oat straw	5.10 Boussingault
Nettle	10.67 Pertius
Thistle	4.03 Pertius
Wheat straw	7.00 Boussingault
Wheat straw	4.30 Saussure
Rye straw	0.30 Karsten
Rye straw	3.60 Boussingault
Corn stalks	12.20 Saussure
Cane stem	1.70 Karsten
Fern	2.90 Mollerat
Fern	5.00 Pertius
Acacia	2.46 Abbene
Grape stalk	8.89 Abbene
Vine pith	7.29 Blengini
Vine pith	3.57 Blengini
Sunflower stalks and leaves	1.93 Wiley
Sunflower stalks and leaves	5.72 Ludogovsky

TABLE X—AVERAGE ANALYSIS OF COTTON SEED HULL ASHES

	Per Cent
Moisture	7.80
Potash	22.75
Sol. phos. acid	1.25
Reverted phos. acid	6.50
Lime	9.60
Magnesia	10.75

from 3 per cent to 13.5 per cent. Some silicate of potassium was always present.

The analyses of woods and wood ashes in Tables XI and XII have been compiled from various sources.[11]

The two analyses given on the top of the right-hand column of this page show the effect of leaching on the composition of wood ashes.

	Per Cent					
	Moisture	Phosphoric Acid	Potash	$CaCO_3$	Insol.	Undeter.
Wood ashes, leached	30.00	1.40	1.1	51.00	13.00	3.5
Wood ashes, unleached	12.00	1.90	5.5	61.00	13.00	6.6

SOME SOURCES OF WOOD ASHES

As a possible source of wood for potash purposes we may turn to our far Western sawmills. Improved sawmill and logging machinery, together with the many more or less well-developed industries using wood waste as a raw material, are doing much to lessen the wastes in the lumber business, but at best a sawmill recovers a scant 40 per cent of the total weight of wood in lumber, lath and shingles. The sawdust, slabs, trimmings and edgings are sold for fuel where there is a market for the material and the rest is burned or used for filling in tide flats and marshes. Within a radius of one small town in the State of Washington there are at least twenty-five sawmills, each of which turns out an average of 150,000 ft. B. M. per ten hour day, and this is excluding the shingle mills.

The total annual output of lumber in this small area is then approximately 1,000,000,000 board feet, or

TABLE XI—ANALYSES OF VARIOUS WOODS AND THEIR ASHES

Material	Air-Dry Wood Contains:			Ash Contains:			
	Ash, per Cent	Phosphoric Acid, per Cent	Potash, per Cent	Phosphoric Acid, per Cent	Potash, per Cent	Lime, per Cent	Magnesia, per Cent
Alder wood	0.375	.....	.....	.....	.....	.....	.....
Alder wood	1.390	.....	.....	.....	.....	.....	.....
Ash wood	0.32	0.012	0.149	3.58	46.04	23.57	0.60
Ash wood	2.30	.....	.....	.....	.....	.....	.....
Ash wood	1.22	.....	0.074	.....	.....	.....	.....
Beech wood	0.58	.....	0.145	.....	.....	.....	.....
Beech bark	.....	.....	0.153	.....	.....	.....	.....
Beech red, wood	0.40	.....	.....	.....	.....	.....	.....
Beech red, wood	0.612	.....	.....	.....	.....	.....	.....
Birch wood	0.275	.....	.....	.....	.....	.....	.....
Birch wood	1.030	.....	.....	.....	.....	.....	.....
Birch charcoal	0.800	.....	.....	.....	.....	.....	.....
Boxwood wood	.....	.....	0.226	.....	.....	.....	.....
Cedar wood	.....	.....	.....	.....	4.81	.....	.....
Chestnut wood	0.16	0.011	0.029	6.76	18.10	49.18	2.11
Chestnut bark	3.51	0.014	0.278	3.25	7.93	47.02	0.01
Dogwood wood	0.68	0.057	0.190	8.51	28.04	38.93	6.80
Dogwood bark	9.87	0.140	0.341	1.42	3.46	49.20	1.40
Elm wood	2.55	.....	0.390	.....	.....	.....	.....
Elm wood	2.28	.....	.....	.....	.....	.....	.....
Eucalyptus wood	0.35	.....	0.024	.....	10.00	.....	.....
Ferns	3.64	.....	0.626	.....	.....	.....	.....
Fir wood	0.23	.....	.....	.....	.....	.....	.....
Fir bark	1.78	.....	.....	.....	.....	.....	.....
Fir charcoal	1.44	.....	.....	.....	.....	.....	.....
Fir needles	2.90	.....	.....	.....	.....	.....	.....
Hickory bark	3.97	0.061	0.141	1.54	3.56	46.82	2.59
Hickory wood	1.050	.....	0.241	.....	.....	.....	.....
Magnolia wood	0.36	0.032	0.071	8.75	19.54	38.94	8.05
Magnolia bark	2.98	0.095	0.192	5.31	11.87	23.64	4.89
Maple bark	9.49	0.421	1.197	4.44	12.61	37.91	3.25
Nettles	.....	.....	2.503	.....	.....	.....	.....
Oak, post, wood	0.77	0.070	0.169	9.00	21.92	46.39	6.88
Oak, post, bark	12.10	0.116	0.249	0.96	2.06	52.04	0.65
Oak, red	6.29	0.103	0.179	1.63	2.84	50.51	.....
Oak, red, wood	0.57	0.060	0.140	10.55	24.66	48.26	5.38
Oak, white, bark	5.95	0.074	0.125	1.24	2.10	52.73	1.62
Oak, white, wood	0.26	0.025	0.106	9.48	42.16	29.85	3.43
Oak, white, wood	1.35	.....	0.153	.....	.....	.....	.....
Oak, white, wood	0.815	.....	0.130	.....	.....	.....	.....
Oak leaves	4.70	.....	.....	3.35	3.74	29.03	.....
Pine, burr, wood	1.09	.....	.....	3.31	6.92	10.30	.....
Pine, wood	0.34	.....	0.045	.....	.....	.....	.....
Pine, Georgia, wood	0.033	0.012	0.050	3.82	15.35	55.24	6.25
Pine, Georgia, bark	0.037	0.013	0.024	1.99	3.56	34.14	2.45
Pine, Oldfield, bark	1.94	0.095	0.077	4.88	3.96	27.95	3.10
Pine, Oldfield, wood	0.18	0.007	0.008	4.11	3.85	67.73	6.54
Pine, straw, mixed	1.65	.....	.....	4.28	2.08	14.47	.....
Pine, yellow, wood	0.23	0.010	0.045	4.18	19.70	65.53	3.20
Pine, black, wood	0.21	0.009	0.030	4.33	14.30	58.98	0.50
Poplar, wood	.....	.....	0.075	.....	.....	.....	.....
Poplar, wood	1.306	.....	.....	.....	.....	.....	.....
Poplar, wood	0.800	.....	.....	.....	.....	.....	.....
Sycamore, wood	0.99	0.121	0.230	12.23	23.17	31.62	0.62
Thistles	.....	.....	0.500	.....	.....	.....	.....
Vetch	.....	.....	2.750	.....	.....	.....	.....
Vines	3.40	.....	0.550	.....	.....	.....	.....
Willow	2.80	.....	0.285	.....	.....	.....	.....
Wormwood	.....	.....	7.300	.....	.....	.....	.....

[11]Karsten, Berthier, Mollerat, Saussure, Winkler, Hertwig, etc.

Table XII—Analyses of Wood Ashes—Berthier*

Source of Ashes	Soluble in Water							Insoluble in Water						
	Carbonic Acid, per Cent	Sulphuric Acid, per Cent	Muriatic Acid, per Cent	Silicic Acid, per Cent	Potash per Cent	Soda per Cent	Total per Cent	Carbonic Acid, per Cent	Phosphoric Acid, per Cent	Silicic Acid, per Cent	Lime per Cent	Magnesia, per Cent	Oxide of Iron, per Cent	Oxide of Manganese, per Cent	Total per Cent
White beech wood	.....	.....	.....	.....	.....	.....	19.22	26.92	8.11	4.05	31.31	6.33	1.30	2.76	80.78
White beech charcoal	4.43	1.30	0.83	0.18	9.12	2.14	18.00	24.43	7.22	3.20	35.75	5.70	0.08	5.70	82.08
Red beech, wood	3.65	1.19	0.85	0.16	10.45		16.30	27.53	4.77	4.85	35.66	5.86	1.25	3.77	83.70
Oak wood	2.88	0.97	0.01	0.02	8.11		12.00	34.99	0.71	3.36	48.41	0.53	.....	.....	88.00
Oak charcoal	4.39	0.90	0.62	0.15	9.43		15.50	26.91	6.27	1.52	39.95	7.15	0.09	2.60	84.50
Oak, dark	1.45	0.37	0.04	0.05	4.33		6.25	37.22	....	1.03	47.78	0.75	....	6.98	93.75
Lime wood	2.96	0.81	0.19	0.17	6.55		10.80	35.75	2.51	1.80	46.53	1.97	0.09	0.54	89.20
Birch wood	2.72	0.37	0.03	0.16	12.72		16.00	26.04	3.61	4.62	43.85	2.52	0.42	2.94	84.00
Alder wood	....	1.24	0.06	....	.....		18.80	25.17	6.25	4.06	40.76	2.03	2.92	....	81.20
Fir wood	7.34	3.75	....	1.09	15.32	22.55	50.05	10.75	0.90	6.50	13.60	4.35	11.15	2.75	50.00
Pine wood	2.89	1.67	0.92	0.18	4.41	3.53	13.60	32.77	0.91	4.19	38.51	9.56	0.09	0.36	86.40
Mulberry wood	5.82	2.09	1.01	....	13.16	2.91	25.00	31.75	1.36	2.19	34.85	3.48	0.38	0.98	75.00
Elder wood	7.71	2.06	0.13	0.06	21.54		31.50	22.06	5.83	2.25	34.57	1.76	0.08	1.26	68.50
Fern	4.35	1.62	3.19	.....	19.84		29.00	17.96	5.68	15.48	30.39	0.50	0.50	0.50	71.10

*Retabulated from Knapp's Chemical Technology.

roughly 1,500,000 tons, assuming the low figure of 3000 lb. per 1000 ft. as the average weight of green lumber. If the manufactured lumber represents even 50 per cent of the weight of the logs and half the waste is sold for fuel purposes there is 750,000 tons of actual waste produced in this locality annually, a possible source for 1000 tons of excellent potassium carbonate, worth $85,000 to $100,000 at ordinary market rates and over $400,000 at the present rate (August, 1915).

Undoubtedly there is plenty of wood being burned by the Western sawmills to produce several times this quantity of potash. As the burners are now operated a large share of the ash is lost, due to the draft. To recover all the ashes a downcomer, together with some means for separating the ashes from the swiftly moving gases, such as a dust catcher, would have to be provided. Difficulties of a like nature have been overcome with blast furnaces and smelters, so that no serious obstacles should be encountered.

The sensible heat of the waste gases could be used for preheating the liquor where the leaching and burning operations were carried on at the same place. With properly designed burners located at the various mills the ash could be collected and sent to a leaching plant without excessive transportation charges.

It might be possible to recover considerable ash in addition from the brush and slashings which are often piled and burned in the logging operations and in the clearing of logged-off land. Several lumber companies in Washington have estimated that there are 40 cords of wood in the average acre of stumps and waste after logging operations. The waste in this part of the country would consist essentially of Douglas fir, Western hemlock and Sitka spruce. Should water freight rates between southern California and Washington ports be sufficiently low it might be possible to combine wood ashes with those produced from kelp at the seashore, thus eliminating several leaching plants and permitting production on a larger scale.

Hardwood distillation plants use considerable quantities of wood and charcoal for fuel, the ash of which is available for potash manufacture in districts where a number of plants are in close proximity. Hardwood ashes are richer in potassium than those from softwood.

Where cottonseed hulls are burned for fuel or any quantity is thrown to waste, they should be considered as a source of potash. It is hardly necessary to state, however, that the demand for potash in this country could in no way be supplied from these sources.

Peat.—According to the U. S. Geological Survey the total production of peat in the United States was 47,093 short tons.

Barometric Condensers.—The Mesta Machine Co., Pittsburgh, Pa., has issued Bulletin R, describing its barometric condensers for vacuum installations.

The Dow Chemical Company, Midland, Mich., the American manufacturer producing indigo, has increased its capital stock from $1,500,000 to $3,000,000, the additional stock being distributed as a dividend.

Erecting Acid Plants.—One indication of the unusual activity in the sulphuric acid industry is the fact that the Chemical Construction Company, Charlotte, N. C., have contracts for the erection of several concentrating plants, six Glover towers and six Gay-Lussac towers. This equipment consists of acid-proof brick and cement with no lead casing around the towers.

Canadian Salt Industry.—In Bulletin No. 325 of the Canadian Department of Mines, Mr. L. Heber Cole describes the occurrences of salt in Canada and gives a very complete account of the technology of its manufacture. A chapter on the allied industries, such as caustic soda, chlorine, etc., is also included. The report contains many illustrations, maps and diagrams of salt beds, springs, and apparatus for commercial production and discusses the present status of commercial salt production in Canada.

New Portland Cement Plant.—The Fuller Engineering Company of Allentown, Pa., has just closed the contract for the new 2000-barrel-per-day Portland cement plant for the Consumers' Portland Cement Company of Chicago. This plant is to be built at Foreman, Ark., and will be modern in every respect and electrically driven throughout with individual motors. All the latest approved methods of manufacturing will be incorporated, including a complete installation of Fuller dreadnought mills.

Rail Tests.—The Titanium Alloy Manufacturing Co. has issued Rail Reports, Bulletin No. 8, describing examinations of open-hearth rails for the purpose of determining carbon segregations and merit comparison. The rails examined were Standard A and titanium-treated and the results are represented in diagrams. Sulphur prints are given of all test pieces, showing the segregation. The following summary shows the results of these segregation tests:

Segregation	Number of Pieces Standard	Titanium-treated
0-12 per cent	45	95
12-15 per cent	5	4
15-30 per cent	49	1
30-40 per cent	8	1
Over 40 per cent	4	0

A diagram representing merit percentages, calculated by the Wickhorst formula from analyses and tests made on the above samples, shows titanium treatment to have considerably increased the merit.

Flotation of Joplin-Galena Slim

BY GEORGE BELCHIC AND GLENN L. ALLEN

The Joplin-Galena slimes constitute the material that overflows from the settling tanks and deposits in slime ponds. It may be divided into two classes: (1) slimes formed from a free milling ore, and (2) slimes formed from a "chatty ore," the latter being an ore in which the minerals are finely disseminated in the gangue rock and consequently requires finer crushing. The following screen analysis will suffice to show the difference in fineness of the material, as well as the assay, of slimes formed from chatty and free-milling ores:

Table I.—Slimes formed from a chatty ore taken from a Joplin mill. This material assays 6.55 per cent metallic zinc, and 99 per cent of it passes through 150 mesh.

Table II.—Slimes made from a free milling ore, taken from a Galena, Kan., mill, and assaying 7.82 per cent metallic zinc.

TABLE I

Opening, Inches	Mesh	Sample Weight, Grams	Per Cent	Per cent Cumulative Weights	Per Cent Zinc
All pass through ...0.0082	65	....	....	....	..
Retained on..0.0058	100	0.5	0.11	0.11	2.0
Retained on..0.0041	150	3.0	0.67	0.78	3.9
Retained on..0.0029	200	87.0	19.33	20.11	5.5
Through...0.0029	200	359.5	79.89	....	6.8
Total		450.0	100.00		

TABLE II

Opening, Inches	Mesh	Sample Weight, Grams	Per Cent	Per cent Cumulative Weights	Per Cent Zinc
All pass through ...0.0110	50	....	....	....	..
Retained on..0.0091	60	9.0	1.84	1.84	3.41
Retained on..0.00675	80	5.0	1.04	2.92	2.06
Retained on..0.0055	100	12.0	2.48	5.40	2.77
Retained on..0.0036	150	21.0	4.35	9.75	3.59
Retained on..0.0020	200	268.0	55.48	65.23	7.86
Through...0.0020	200	168.0	34.81	....	10.30
Total		483.0	100.00		

Table III gives the analyses of six samples of slimes taken from various ponds in Galena, Kan., these samples covering the district geographically.

TABLE III

Sample	Per Cent Zinc	Per Cent Lead	Per Cent Iron	Per Cent Insoluble
1	3.77	0.69	4.58	85.87
2	7.82	1.09	4.46	70.75
3	5.57	0.37	10.78	78.81
4	3.69	0.41	3.08	88.87
5	7.43	0.45	7.81	81.23
6	4.20	0.26	4.18	81.27

The flotation tests were carried out with a laboratory experimental machine, and over a hundred tests were made, in order to establish the following factors:

1. Kind and amount of oil.
2. Effect of adding acid.
3. Effect of temperature.
4. Ratio of dilution of pulp.
5. Speed of agitation of propellers.
6. Time of agitation.

The oils used in the tests were pine oil, creosote oil, tar oil, crude petroleum, crude carbolic acid, cresylic acid, eucalyptus oil, rosin oil, oleic acid, rape seed oil and various combinations of the above. Tests were also made with mixtures of the above oils with carbon-bisulphide, benzine-sulphonic acid, kerosene, turpentine, etc. Summarizing the results of the numerous tests the following facts were established:

1. Good results may be obtained without the use of sulphuric acid, although a small quantity (0.5 per cent of the weight of dry slime) in many instances brought the extraction somewhat higher without, however, increasing the zinc tenor of the froth-concentrate. With Kansas crude oil the addition of sulphuric acid is detrimental to flotation. Better results may be obtained if benzine-sulphonic acid be used instead of sulphuric acid with both crude petroleum and tar oils.

2. Comparatively high temperature (60 deg. C.) gives better results with light pine oils and rape seed oil, while room temperature (25 deg. C.) is better suited for the heavy tar oils and crude petroleum.

3. Speed of agitation was found best between 1200 and 1500 r.p.m. Above 1500 r.p.m. gangue material is often thrown over with the froth. Excessive speed of rotation produces, in many instances, air bubbles as large as 2 in., which carry readily both gangue and sulphide particles.

4. Pulp dilution varies with the fineness of the slimes. With very fine slimes a 7:1 dilution was found to give the best results. With coarser slimes a 3:1 dilution worked satisfactorily. With those slimes, in which a large percentage of the particles is in colloidal form, greater dilution is necessary to suspend the particles and allow the oil to surround the sulphide grains. Mechanical adhesion of sulphide and gangue particles in the froth are readily visible in slimes of this character.

5. Time of agitation in these tests ranged from five to ten minutes. This, however, is not so important since on a commercial scale the operation may be continuous.

6. The oils that gave the best results were the following:

Pine oil (specific gravity 0.937) gave a froth-concentrate assaying 53 per cent metallic zinc, with an extraction of over 73 per cent; 2.5 lb. of oil and 10 lb. of sulphuric acid were used per ton of dry slime. The slime feed assayed 5.17 per cent metallic zinc with a trace of lead.

Rape seed oil (specific gravity 0.85) gave a froth-concentrate assaying 48 per cent metallic zinc, with an extraction a little over 55 per cent when used in quantity of 10 lb. of oil per ton of dry slime, and without the use of acid. The slime feed assayed 5.17 per cent metallic zinc with a trace of lead.

Benzine-sulphonic acid and tar oil (1:1 by weight) gave good results when used in the quantity of 8 to 10 lb. of the mixture to the ton of dry slime; a froth-concentrate assaying 56 per cent metallic zinc with an extraction of over 50 per cent was obtained. The slime feed assayed 3.69 per cent metallic zinc and 0.41 per cent metallic lead.

Carbon-bisulphide and rosin oil (1:1 by weight) gave a froth-concentrate assaying 40 per cent metallic zinc, with an extraction of 50 per cent when used in the quantity of 5 lb. of the mixture to the ton of dry slime. The feed assayed the same as the one above.

These preliminary results would indicate that the Joplin-Galena slimes, which at present are a waste product, might be treated on a commercial scale by flotation, and by this means the loss of zinc in milling in this district might be greatly reduced.

Division of State Chemical Research,
Department of Chemistry, University of Kansas,
Lawrence, Kansas.

The Driver-Harris Wire Co., Harrison, N. J., will erect a brass foundry, the contract having been let.

California Gold and Petroleum Yield.—The gold yield of 999,113 fine ounces in 1914, valued at $20,653,496, was, with the exception of 1883, the greatest of any year in California since 1864, according to the State Mining Bureau. California leads all States in this item, as well as petroleum, which is the largest single item, the 1914 figures for which were: 102,881,907 barrels, valued at $47,487,109.

Electrolytic Antimony Refining*

BY ANSON G. BETTS

It is already known that antimony may be electrolytically deposited in a very satisfactory mechanical condition from the fluoride solution, and that the deposit does not carry down antimony salt with it, as the deposit from the chloride solution is apt to do. I have shown that the fluoride solution, for an easy anode reaction, should not contain sulphates or other oxygen acids, or their equivalents, because the anode reaction tends to the formation primarily of antimony sulphate, for example, which quickly decomposes into an insoluble basic sulphate (Transact. Am. Electrochem. Soc., vol. 8, p. 187, 1905). This material insulates the anode surface, and by raising the electromotive force helps the solution of the less-readily attacked constituents of the anode. The fluorine anion is relatively sluggish, and in presence of the more easily transported sulphion, for example, forms at the anode a small proportion only of the directly soluble antimony fluoride. To achieve at once complete solution of the anode as fluoride, it is necessary to exclude all other anions from the solution.

It has not been known how the impurities of the antimony anodes will behave. Lead can be expected to form lead fluoride, which by reason of its insolubility may remain largely in the anode slime. Bismuth also makes an insoluble fluoride in the presence of free hydrofluoric acid, and in the absence of stronger acids, and may be expected to remain in the anode slime, if the solution is rightly proportioned.

Silver stands about 0.6 volt below antimony in the scale of electromotive forces of solution, and could only be expected to remain in the anode residue as metal; gold would, of course, act likewise, and for the same reason.

Copper is readily dissolved as anode in a fluoride solution, and stands so near antimony in the scale that it might seem unlikely that copper would remain undissolved if there is the usual polarization voltage at the anode surface of 0.1 to 0.2 volt, even with a pure fluoride solution. It will be shown by what follows that generally copper does not dissolve at the anode, and knowing the ready solubility of copper fluoride, we can be quite sure that the copper remains in the slime in the metallic condition.

Arsenic is also very near to antimony in the electrochemical scale, and is thought to have a higher deposition voltage than antimony. One would expect that arsenic would dissolve from the anode, and not depositing so rapidly as the antimony, would accumulate in the solution until by virtue of its increasing concentration it finally deposited in the cathode metal as fast as it dissolved from the anode. This expectation was not realized experimentally.

The first experiment was made in a paraffined wood cell holding about 1500 c.c., fitted with a stirrer which at times stopped working and detrimentally affected the experiment, but not seriously.

The anode was 1 x 4.25 x 6 in. (2.5 x 10.5 x 15 cm.) and weighed 3655 grams. Analysis showed it to contain 74.79 per cent antimony, 11.88 arsenic, 3.98 lead, 3.25 copper, 0.16 iron, 2.58 bismuth and 0.092 silver.

The solution was made up to contain in 100 c.c., 10 grams of antimony as trifluoride, besides potassium fluoride and hydrofluoric acid in the proportions given by the formula $SbF_3.KF.HF$. The mixture crystallized partly, so the solution was not as strong as was intended.

The cathodes were of copper, spaced about one inch (2.5 cm.) from the surfaces of the anode. The current used varied from two to three amperes, and mostly it was very near 2.1 amperes, corresponding to a current density of 6.6 amperes per square foot, or 73 amperes per square meter. The electromotive force was near 0.6 volt, but this increased after two or three days, as the slime layer grew thicker. The slime was removed occasionally, to prevent this undue voltage with the consequent increased solution of impurities from the anode that one would expect. The deposited metal was removed from the cathodes frequently, and the percentage of impurity it contained was determined. No appreciable quantity of impurity was found in any of it, except about 0.35 per cent of Pb, and some As. The principal results are shown graphically in Fig. 1. It was noted that the percentage of As in the metal deposited only varied a little, depending on the rate of circulation to a slight extent, but more on the current density and on the amount of slime on the anode.

The amount of arsenic in the solution at all times was small, the amount being plotted in Fig. 1. Com-

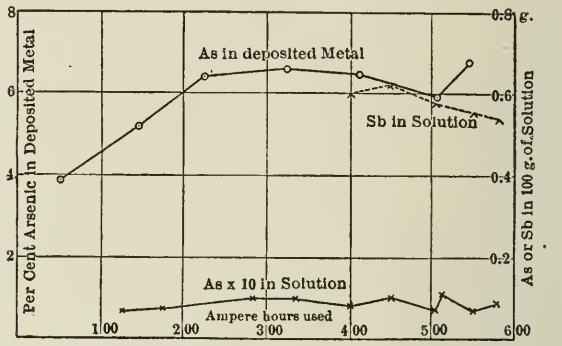


FIG. 1—AMOUNT OF ARSENIC IN SOLUTION AND IN CATHODE DEPOSIT

paratively, the As is far more concentrated in the cathode metal than in the solution, which shows it to be more readily precipitated than antimony. As/Sb in cathode metal approximated to 0.065, while As/Sb in solution approached 0.016.

The deposited metal was at all times hard, solid and non-projecting.

The principal conclusions to be drawn are: (1) there is no difficulty in eliminating lead, bismuth, and copper under these conditions, which are rather severe with so low a proportion of antimony in the anode metal; (2) the solution does not become contaminated with impurities; (3) the physical condition of the deposit is all that could be desired; (4) the required current density is less than is desired and generally used for other metals, and the voltage is a good deal higher; (5) only about half the arsenic could be kept in the anode slime.

The additional analyses which were made in connection with the experiment are given in Table I:

Samples of the cathode metal for analyses were fused under KCN, before the analyses. The weight of anode decomposed was 853 grams, and of metal deposited, about 675 grams. There was 199 grams of slime produced. Some metal was found in the bottom of the cell.

In the preceding experiment the anode contained a larger percentage of impurity than is usual in electrolytic refining of metals. As it was impossible to conclude that with an anode containing less impurity arsenic would remain entirely, or in larger proportion, in the anode residue, another experiment was necessary.

Part of the old anode was melted with an equal

*A paper presented at the San Francisco meeting of the American Electrochemical Society, September, 1915.

TABLE 1

	1 Per Cent	2 Per Cent	3 Per Cent	4 Per Cent	5 Per Cent	6 Per Cent	7 Per Cent
SLIME:							
Arsenic	19 6		18 06	17 46			
Antimony	28 1		21 17	24 57			
Lead	15.4		14.3	14 2			
Copper	10 6		16.3	16 0			
Bismuth	9.85	13.5	13.1	11 7			
Iron	Trace						
Silver							
Amount	48 gr.	30 gr.	39 gr.	46 gr.	36 gr.		
DEPOSITED METAL:							
Arsenic	3.89	5 18	6 36	6 59	6 45	5 92	6 81
Antimony	94 73	93.32	91.97	91.33	91 88		
Lead					0 35		
Copper					None		
Bismuth					None		

quantity of fresh antimony, and was cast into a new anode, which should have had about the following composition: 87.5 per cent antimony, 5.95 arsenic, 2.0 lead, 1.65 copper, 1.3 bismuth, and 0.16 iron. (It was not analyzed.)

The solution and cathodes were the same as were used in the former experiment. The current density was about 6 amperes per square foot, and electromotive force 0.6 to 0.65 volt. The electrolysis was continued for about 36 hr., and 250 grams of the anode was decomposed, while 221 grams was deposited on the cathodes. The anode slime was very soft and readily removed, and did not interfere with the solution of the metal underneath, as was the case in the first experiment.

The electrolyte was analyzed at intervals for As, which was found to amount to 0.06 gram As per 100 c.c. during the entire experiment. The first 143 grams deposited contained As, 4.23 per cent; Cu, Pb, Bi, none, and the 78 grams following contained 13.9 per cent As and 25.3 per cent Sb.

The conclusions are these: (1) With an anode of this composition the electrolysis goes smoothly, and there is no need of scraping the anode slime from the anodes; (2) a larger proportion of the arsenic goes into the cathodes, viz.: 60 per cent as against about 40 per cent of the total As in the first experiment. The deposit was physically good, perhaps a little better than before. Cu, Pb and Bi may be separated from antimony in this way.

When a solution of arsenious chloride is heated with metallic copper, a black arsenide of copper is precipitated on the copper. To learn whether the presence of copper would tend to retain arsenic in the anode slime as an arsenide of copper, thus yielding a purer antimony deposit at the cathode, an anode was made containing about 84.8 per cent antimony, 5.4 arsenic, 1.8 lead, 6.65 copper and 1.2 bismuth.

In refining this anode, the solution and conditions were the same as in the preceding experiment, except that the stirring was even more vigorous this time. At the end of 31 hr., the solution contained 0.045 per cent As and the deposited metal 3.15 per cent As, with only a trace of copper.

The result shows the effect of copper in holding back arsenic in the slime to be certainly small, if there is any such effect at all.

Following up the discovery that arsenic tends to deposit from the fluoride solution more rapidly than antimony, in proportion to the quantities present, it becomes important to know if in depositing antimony from the fluoride solution containing sulphuric acid, with an insoluble lead anode, as is sometimes done in treating Pb refinery anode slime, the arsenic present in the solution could not be collected with the first part of the antimony, thus producing the latter, and perhaps, greater part of the antimony in pure form.

One thousand four hundred cubic centimeters of solution was used containing about 124 grams of antimony and 5.3 grams of As as trifluorides, 1 or 2 grams HF, and 65 grams H_2SO_4; or per 100 c.c. Sb 8.85 grams, As 0.38 grams, HF about 0.1 gram, H_2SO_4 4 grams. The solution was electrolyzed at the ordinary temperature with two copper cathodes, having an active area of 24 sq. in. (150 sq. cm.), and with a lead anode, cotton-covered, having an active area of about 2.5 sq. in. (15.6 cq. cm.). The current was 1.2 amperes, or a cathode current density of 7.2 amp. per square foot (80 per sq. m.).

Analysis of the solution was made at intervals for antimony and arsenic, the difference between two consecutive analytical results showing the quantities deposited. The results are plotted as Fig. 2, in which the curves show grams of antimony, and twenty times the grams of arsenic per 100 c.c.

Only one analysis of deposited metal was made, that of the first 9 grams deposited, which contained 5.0 per

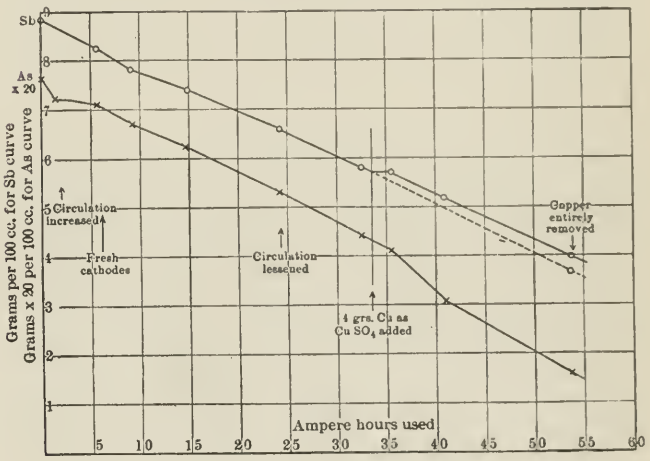


FIG. 2—ANTIMONY AND ARSENIC ANALYSES

cent As. The proportion of As to Sb at the start was 4.3 per cent.

Referring to the figure, the Sb and As curves, up to 34 amp. hr. show that the Sb and As are depositing out in very nearly the same proportion as they exist in the solution. If any separation of the two were practicable in this way, the favorable conditions of this experiment, low current density, and very good circulation, should show it. During the experiment the rate of circulation was changed to see if it made any difference, but none was detected.

After about 34 amp. hr. of current passed, and it was seen that no practicable separation of As and Sb was indicated with this solution, copper sulphate was added to the solution, to see if copper in depositing would have any tendency to carry As out with it. Furthermore, copper is usually present to some extent in the antimony fluoride solutions resulting from the treatment of lead-refining slimes by hydrofluoric acid, and in removing that copper by electrolysis with a very low density, arsenic might be found to separate with it.

The conclusion of the experiment showed that copper has a tendency to do this, but the effect is too small to be of any use.

The continuation of the Sb curve in a dotted line is derived by subtracting from the antimony found by analysis, the antimony equivalent of the copper added.

Calculating the ratios of antimony and arsenic in the deposited metals and in the solution, in the beginning of this experiment they are respectively about 19.1 and

23.1, so that the relative speed of deposition of antimony and arsenic in proportion to the amounts present, is about 1: 1.2.

With the solution used in the antimony refining experiments, the principal difference being that the refining solution contained no sulphuric acid, the corresponding ratio is about 1: 4.2. The presence of sulphuric acid interferes to a large extent with the tendency toward separation of the two elements.

With such a refining solution as that used in the first experiment described, there is sufficient difference in the behavior of arsenic and antimony to make possible a differentiation of the deposited metal into two parts, one a good deal lower in arsenic and the other higher, by alternately causing the refining solution to circulate rapidly and remain at rest. If the solution were electrolyzed quietly, keeping the anode away from the cathode, and removing a large proportion of the metal from the solution in contact with the cathodes, the deposited metal should contain only about 1 per cent of As instead of 6 per cent, as the total quantity of As present in the solution is so small. If the solution is then rapidly circulated so that the As brought into solution from the anode could be quickly brought to the cathodes, the proportion of As deposited should be much greater than 6 per cent, perhaps as high as 25 per cent.

The simplest way in which to carry out this idea of producing two quantities of antimony, one very high and one very low in arsenic, is to cause the solution to pass in turn through a cell with strong agitation, and one with as little agitation as possible, preferably arranged so that the heavy solution running down the anode surface could be collected in the bottom of the quiet cell, and siphoned out into the agitated cell.

The apparatus used consisted of one main wooden cell 38 cm. deep by 12.75 cm. by 20.3 cm., with a capacity of about 10 liters, and a series of four auxiliary cells 12.9 cm. deep by 7.75 cm. by 7.75 cm., with a total capacity of about 3 liters.

The main anode, about 1.8 cm. thick by 15 cm. by 30 cm. was suspended in the middle of the main tank, between two copper cathodes.

The first of the small cells, through which the solution from the main tank passed, contained one anode of the same composition as the main anode, and a copper cathode, the active anode or cathode area being about 6.8 cm. by 10 cm.

In the other three tanks anodes of pure Sb, and Cu cathodes were used, of the same size as those in the first of the small tanks. The alloy to be refined contained 84.0 per cent antimony, 5.4 arsenic, 3.6 copper, 3.7 lead and 1.1 bismuth.

The solution was made to conform to the formula SbF_3.NaF.KF.HF, and should have contained 4.4 grams Sb, 1 gram Na, 1.4 grams K, and 0.8 gram HF per 100 c.c. A small quantity of salts crystallized out and a very little solution was spilled, so the solution was undoubtedly somewhat weaker and contained at the end of the experiments only 1.8 per cent Sb. This lowering would, of course, result from the conversion of the lead in the anode to lead fluoride with the reduction of the corresponding amount of antimony.

Some difficulty was experienced in regulating the flow of solution through the tanks, and the stirrers sometimes stopped during the night.

With an electromotive force of 1.35 volts the large tank used (at about 17 deg. C.) 8.5 amp., and the four small tanks in multiple about 15 amp., or current densities of respectively 1.2 and 0.4 amp. per square decimeter (12 and 4 per square foot).

The large tank was fitted with a distributer, so that the heavy solution flowing in from the four small purifying tanks should mix with the light solution at the top of the large refining cell.

The heavy solution running down the anode collected in the bottom of the tank and was continuously removed to the purifying tanks through a rubber tube.

During the first experiment the heavy solution at the bottom of the refining cell and in the purifying cells contained about 6.2 per cent Sb, and the solution at the top of the refining cell 3.3 per cent Sb.

The character of the deposit in the four purifying cells was different, that in the first cell especially being darker, duller and less crystalline, and containing more As, as was expected.

After three days the solution in the first three of the purifying cells contained:

No. 1	0.148 per cent arsenic
No. 2	0.133 per cent arsenic
No. 3	0.122 per cent arsenic

The purification was evidently less complete than could be inferred from the fact that the solution in the first refining experiment contained only about 0.05 per cent As.

After five days the upper three-quarters of the main cathode was collected and melted separately from the bottom quarter. The upper 660 grams contained 3.0 per cent As and the lower 210 grams contained 3.4 per cent As. To the solution was then added enough NaF to correspond to the formula SbF_3.2NaF.KH.HF. The solution crystallized a little, so it was taken out, filtered, mixed and analyzed, showing it to contain 0.07 per cent As, and put back.

After five days more 1060 grams of cathode metal was found to contain 3.18 per cent As.

The analyses of Table II are of the slime produced in the first five days, the second five days, and that taken from the first small cell.

Table II

	First Slime, per Cent	Second Slime, per Cent	Slime in Small Cell, per Cent
Arsenic	8.2	8.17	8.5
Antimony	7.16	7.94	16.7
Lead	26.9	28.1	
Copper	30.1	26.2	
Bismuth	6.53	5.4	

Thinking that a diaphragm might keep the impure anode solution in the refining cell away from the cathodes, a muslin diaphragm was used, reaching nearly to the bottom of the cell. The diaphragm was of two or three thicknesses, spaced ½ in. (1.25 cm.) in the clear from the anode surface. The current was reduced to 5.5 amp. for the large cell and 1.5 amp. for the four small cells in multiple. After six days electrolysis the figures of Table III were obtained by analysis of the products:

Table III

	Grams	Per Cent Arsenic
Upper third	240	3.4
Middle third	275	3.3
Lower third	260	3.3
Small tank No. 1	59	4.6
Small tank No. 2	87	3.9
Small tank No. 3	75	3.9
Small tank No. 4	100	3.9

The absence of a diaphragm was evidently not the weak point in the first part of the experiment, as the result was practically the same either way. The percentage of As in the metal deposited in the four small tanks was evidently much less than indicated from the

ratio of 1: 4.2 for As in metal found in the first experiment. The difference must be due to a difference in the temperature, current density, or composition of the solution.

Another run of four days with the addition of four grams HF per liter yielded products analyzing as stated in Table IV.

TABLE IV

	Grams	Per Cent Arsenic
Main cathode metal	430	3.6
Small tank No. 1	17	6 6
Small tank No. 2	23	6.3
Small tank No. 3	20	6.1
Small tank No. 4	20	5.8
Total of small tanks	80	6 05

The improved, but still unsatisfactroy result, is believed to be due to the presence of more HF in the solution.

The solution (now thrown away) contained 1.8 per cent Sb and 0.06 per cent As, giving a ratio calculated as before of 1:2 since

$$\frac{\text{As in solution}}{\text{Sb in solution}} = 0.033 \text{ and } \frac{\text{As in metal}}{\text{Sb in metal}} = 0.066.$$ Ratio is 1:2

It was concluded that a study of the ratio

$$\frac{\text{As in solution}}{\text{Sb in solution}} : \frac{\text{As in metal}}{\text{Sb in metal}}$$

with varying solution composition, temperature, current density, and perhaps other factors is necessary for successful refining by this method.

Experiments were then made to determine the effect of temperature on the amount of As passing over into the cathodes. As there is a counter e.m.f. even with the fluoride solution, sometimes as high as 0.2 volt, it might be possible by raising the temperature to reduce the anode e.m.f. to a point where antimony but not arsenic could be dissolved.

The solution used contained, in 100 c.c., 3 grams NaF, 11 grams SbF_3 and 1 gram HF. Three small rubber jars were arranged as electrolytic cells at temperatures of 30 deg., 40 deg., and 50 deg., respectively. The current varied from 1 to 1.4 amp., corresponding to a current density per square foot of 14 to 20 amp., with an e.m.f. per cell of about 0.9 volt. After 43 hr. electrolysis the experiment was discontinued with these results:

Thirty degree cell short circuited, 35 grams deposited, in smooth condition at the bottom and rough and flaky on top.

Forty degree cell, 54 grams deposited, rather smooth and even throughout.

Fifty degree cell, 45 grams deposited, in still smoother condition.

The deposits were melted and analyzed for As, with these results:

Temperature, Degrees	Arsenic, per Cent
30	3.5
40	3.6
50	3.9

I tried the purification of antimony from arsenic by crystallizing the melted metal analogously to the purification of lead and bismuth by crystallization. Numerous experiments with antimony-arsenic alloys containing from 3 to 8 per cent of arsenic gave in all cases crystals and liquid portions containing the same percentages of arsenic.

The alkaline sulphide solution of antimony was tried as a refining medium. The solution was made by dissolving 30 grams of SbF_3 in 500 c.c. sodium sulphide solution of specific gravity 1.19. The solution was electrolyzed warm with the same composition of anode as used in the last preceding refining experiments.

After 24 hours' run the cathode deposit averaged 1.0 per cent As and after 48 hours 2.1 per cent As.

Returning to the original idea of refining in the usual way, with the fluoride solution, some of the refined antimony containing about 3 to 3.5 per cent arsenic was cast in the anode and again refined in the same way. About half of the arsenic remained in the anode slime. By several refinings the arsenic may probably be eliminated.

The most positive reaction noted in these experiments is that due to the composition of the solution. An increase in HF is highly beneficial and the presence of sulphates or sulphuric acid is shown to be objectionable. It is likely that the hydrofluoric acid may have contained traces of sulphuric or fluosilicic acid, and the negative results might have been traced to that cause. The effect of alkaline fluorides and ammounium fluoride should be studied, also.

A successful method of electrolytic refining of antimony should receive technical application, inasmuch as present methods do not save the gold frequently present and are incapable of making a product of a high and uniform grade at all comparable to the copper, lead and silver on the market.

Gas Analysis

Technical paper 104 of the Bureau of Mines deals with the "Analysis of Natural Gas and Illuminating Gas by Fractional Distillation at Low Temperatures and Pressures," the authors being G. A. BURRELL, F. M. SEIBERT and I. W. ROBERTSON.

"This publication, which is one of a series dealing with the increase of efficiency in the production and utilization of fuels, describes in detail the results of experiments, made by the Bureau of Mines, with a method of separating and determining the hydrocarbons in gaseous fuels. The method employs fractional distillation in a vacuum at low temperatures. The gas is liquefied, the different constituents separated by proper adjustment of temperatures, the various fractions removed with a mercury pump, and these fractions analyzed by ordinary slow-combustion methods. The method was successfully applied to the separation of hydrocarbons in natural gas and in artificial illuminating gas, and is the only known method applicable to the separation of some hydrocarbons."

The first part of this report describes the results of experiments by which the natural gas used in Pittsburgh, Pa., was separated into its individual paraffin hydrocarbons. The second part describes experiments in which the separation of the illuminants in artificial illuminating gas, that used in Pittsburgh, Pa., and that used in New York City, was effected. Some experiments to determine the practicability of separating gases whose boiling points lie close together, such as ethane and ethylene, are included.

"Each year much experimental work is done in the destructive distillation of different fuels, liquid, gaseous and solid, which yield complex mixtures of different hydrocarbon gases. In reports on these tests some of the gases are not separated, but are invariably lumped together as illuminants (determined by absorption in fuming sulphuric acid, or bromine water) or calculated in the combustion analysis as methane and ethane. By the methods described in this publication the gases can be separated into the individual constituents. Hence a wide field of investigation is opened up, in that a much more exact study of combustion processes can be made and chemical changes more closely followed and better understood."

The Electrolytic Precipitation of Gold, Silver and Copper from Cyanide Solutions*

BY G. H. CLEVENGER

(*Concluded from page* 806)

Practice at San Sebastian, Salvador

The original electrolytic precipitation plant installed at Butters' Salvador Mines, San Sebastian, was similar to the Minas Prietas plant.

However, after being placed in operation it was found necessary to modify the practice in several important particulars. The two wooden containing boxes used were 30 ft. (9 m.) long, 10 ft. (3 m.) wide, and 4 ft. 8 in. (1.4 m.) in depth. The bottom was given a slope to one side at the rate of 1 in. per foot (8 cm. per m.). Each box was divided into twelve compartments, ten of which were used for precipitation, the last two merely serving as settlers. Each compartment contained 25 anodes and 24 cathodes.

The anodes were rolled lead plates $\frac{1}{8}$ in. (0.3 cm.) thick, 22 in. (55 cm.) wide and 48 in. (120 cm.) long. For some time the anodes were peroxidized in a special cell using an electrolyte consisting of 1 per cent of potassium permanganate and 2 per cent sulphuric acid; but later untreated lead plates were used.

At first tinplate cathodes similar to those used at Minas Prietas were tried, but certain difficulties arose which made it necessary to abandon the tinplate cathode. The original intention was to deposit the gold and copper as a non-adherent slime, as at Minas Prietas, but despite the fact that a higher current density was used the gold and copper were deposited upon the cathodes as a quite firmly adherent coating.

*A paper read at the San Francisco meeting of the American Electrochemical Society, September, 1915.

The predominating metal in the solution at Minas Prietas was silver, but at San Sebastian it was copper. The well-known fact that silver is very prone to give non-coherent coatings, while copper has a strong tendency to give adherent coatings, seems to offer a ready explanation of this difference.

The removal of the strongly adherent copper-gold plating from the tin cathodes presented a most difficult problem. Various expedients for removing it were tried, such as heating the cathodes with a gasoline torch, scraping and pounding them, etc. After these various heroic measures had proved ineffective, it was decided to return to the lead-foil cathode cut into strips, as used in the Siemens-Halske process. When it was desired to "clean up," the lead-foil strips were removed, ground and shipped to smelters for the separation of the metals.

The current was supplied by a belt-driven Siemens-Halske dynamo giving 450 amp. at 30 to 35 volts. The current density was 10 amp. per square foot (110 per sq. m.) of anode surface, and the voltage across anodes and cathodes was 4 to $4\frac{1}{2}$.

This general practice was continued until C. P. Richmond modified it so that the metals could be separated locally. The lead-foil cathodes were replaced by sheet-lead cathodes 1/16 in. (0.15 cm.) thick, 22 in. (55 cm.) wide and 48 in. (120 cm.) long, so arranged that they could be readily removed from the containing box. To this end, the connecting wires for the cathodes, instead of being soldered to the copper bus bars, were clamped by wing-nuts in split studs screwed into the bus bars.

The general arrangement of the preciptation box is shown in Fig. 3. The wires from five anodes and cathodes of opposite compartments were laid in each

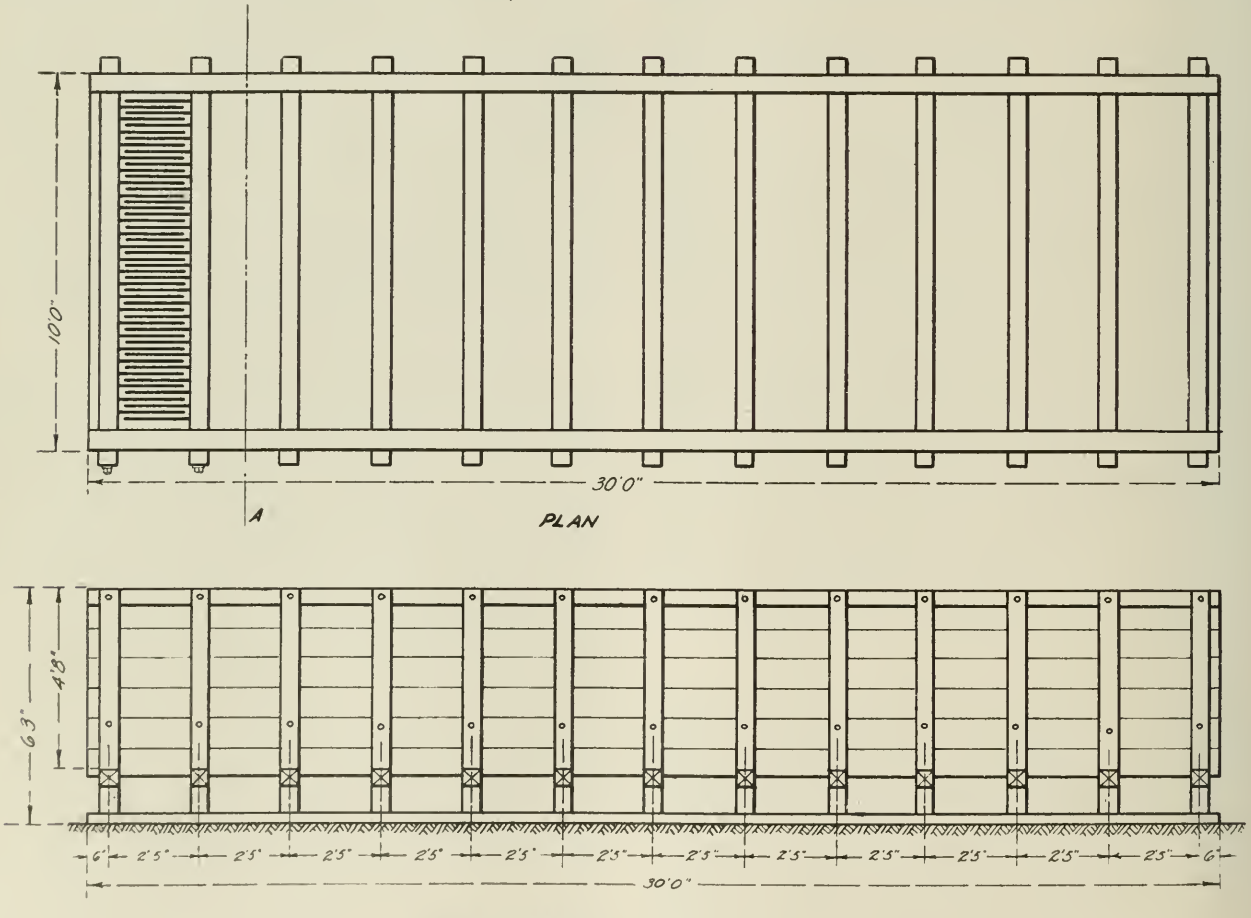


FIG. 3—ELECTRIC PRECIPITATION BOX, SAN SEBASTIAN, SALVADOR

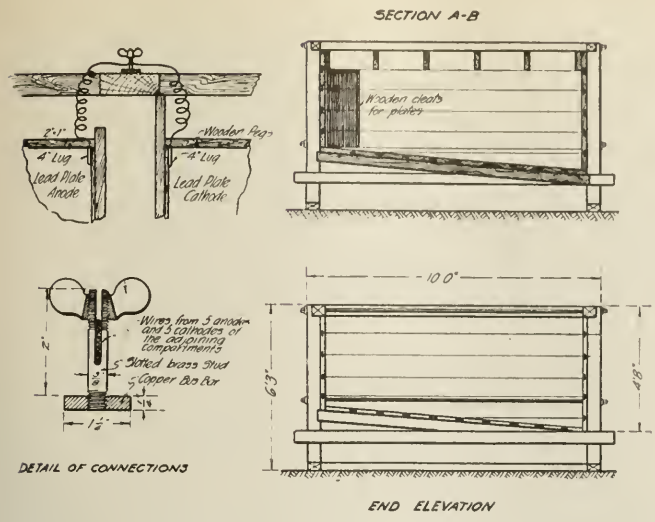


FIG. 3A—DETAILS OF FIG. 3 (ELECTRIC PRECIPITATION BOX)

slot and a tight connection secured by screwing down the wing-nut. The studs were spaced 19 in. apart and six of them connected the cathodes of one compartment to the anodes of the adjoining compartment. By this arrangement it was possible to remove any of the cathodes without interrupting the flow of current or solution.

At San Sebastian it was found advantageous to operate so as to keep the concentration of the copper down to a point where it did not interfere with gold extraction, and precipitate the remaining gold by zinc shaving. This was done despite the fact that zinc was said to interfere with electrolytic precipitation in South Africa.

The solution leaving the electrolytic boxes was divided between two zinc boxes, each 22 ft. (6.6 m.) in length and having 14 compartments, 2 ft. (60 cm.) by 1 ft. (30 cm.) and 2 ft. (60 cm.) deep, filled with zinc shaving. The ore treated was a high-grade gold ore containing considerable pyrite and sufficient copper left in the soluble form after the roasting which preceded cyanide treatment, to occasion trouble in cyanidation unless electrolytic precipitation were used.

The average gold content varied, but at the time that electrolytic precipitation was in use ranged from 2 to 4 oz. (58 to 117 g.) per ton. The soluble copper varied from ½ to 2½ lb. (0.23 to 1.14 kg.) per ton. The ratio of gold to copper in the electrolytic deposit ranged from 1 to 7 up to as high as 1 to 25, but generally was between the limits of 1 to 9 and 1 to 14.

The average results of two months, taken at random, will give a general idea of the performance. During this period there was treated 45 tons of ore daily, averaging 2.27 oz. (66.2 g.) gold per ton. Approximately 150 tons of solution was precipitated daily. The average content of the head solution was: Gold, 0.79 oz. (13.0 g.) per ton; copper, 0.075 per cent; cyanide, 0.118 per cent. The average content of the tail solution from the foot of the zinc box was: Gold, 0.004 oz. (0.117 g.) per ton; copper, 0.048 per cent; cyanide, 0.154 per cent. The percentage of gold in the deposit at the head of the electrolytic box was about 7; at the foot of the box it was about 3. The current density was 1.0 amp. per square foot (11 per sq. m.) of cathode surface. The voltage across the anodes and cathodes of each compartment was 4 to 4½.

During the treatment of the ore there was consumed 7.2 lb. (3.27 kg.) of sodium cyanide per ton. There was precipitated in the electrolytic boxes 1.5 lb. (0.68 kg.) of copper and apparently there was regenerated 1.92 lb. (0.87 kg.) of cyanide, in terms of potassium cyanide, per ton of ore treated. Eighty to 90 per cent of the gold and most of the copper was precipitated in the electrolytic boxes. Passage through the zinc boxes brought the total percentage of gold precipitated up to 99.5.

The zinc boxes precipitated little copper, despite the fact that the solution invariably contained copper at this point. Under normal conditions the percentage of copper in solution remained more or less constant, any increase through contact with the ore being precipitated by the electrolytic boxes. When the copper built up in the solution, as was sometimes the case through treating ore containing an unusually high percentage of copper, the bad effect was at once noted upon the gold extraction.

ELECTROLYTIC REFINING OF THE CATHODE DEPOSIT

After the cathodes had remained in the precipitation boxes 20 to 30 days, during which time they had increased in weight from 8 to 12 lb. (3.5 to 5.5 kg.), they were removed and, after draining, were connected as anodes in a special electrolyzing cell shown in detail in Fig. 4, containing an electrolyte of 2 to 3 per cent sulphuric acid, which was thrown away when its strength was reduced to 1 per cent.

They were here enclosed in compartments so constructed as not to interfere with the free passage of the current, and which served to collect the gold slime freed by solution of the copper of the deposit. The compartments consisted of a wooden frame having a pocket at the bottom somewhat larger than the cathode plate, covered on both open sides with cotton twill held in place by tacking. The cathodes used in the refining boxes were lead plates 1/16 in. (0.16 cm.) thick, 22 in.

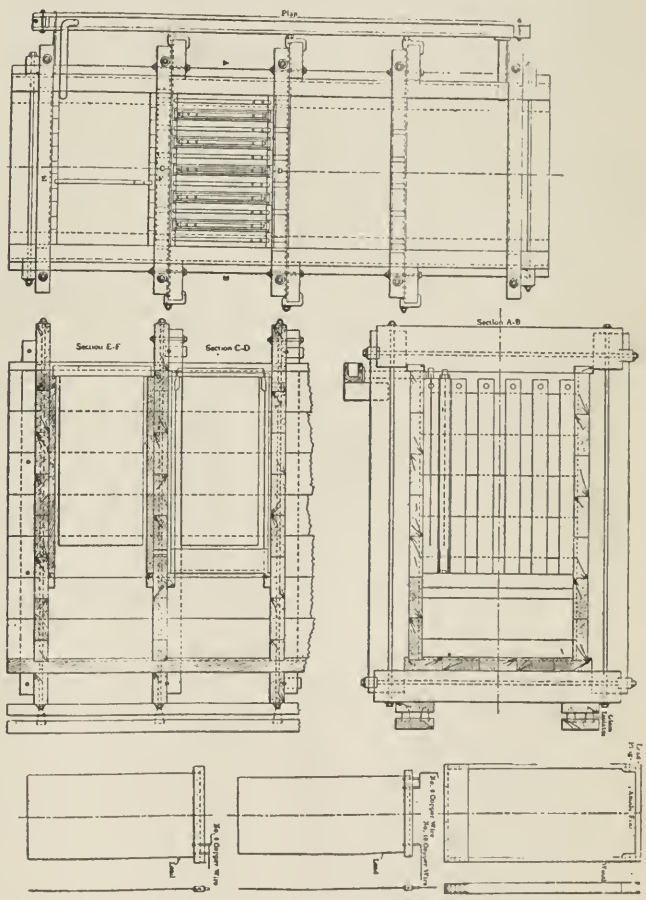


FIG. 4—ACID REFINING TANK, WITH DETAILS OF ANODE AND CATHODE

(55 cm.) wide and 48 in. (120 cm.) long. The refining box contained four compartments, each holding 5 anodes and 6 cathodes. The spacing between the plates was 4 in. (10 cm.). The compartments were connected in series and received a total current of 450 amp.

The average voltage across the electrodes of each compartment was 8. The current density was approximately 5 amp. per square foot (55 per sq. m.) of anode surface.

The copper was deposited at the cathode as a flocculent non-adherent precipitate, which collected in the bottom of the main cell, while the gold slime remained inside of the cloth-sided compartments surrounding the anodes. When the operation had proceeded to the point where all of the copper of the copper-gold deposit was dissolved, the anode plates were removed, washed and replaced again in the regular precipitation box as cathodes. The time required for dissolving the deposit on a plate was from 48 to 72 hr.

Two electrical connections were provided for each cathode; one, a No. 10 copper wire, used when the plate functions as cathode in the regular precipitation box, and the other a No. 6 wire, which is used for carrying the heavier current employed in the refining cell. Both wires are permanently soldered to the lead lugs cast on the plate.

Beginning at the head of the precipitation box the cathodes were removed and, as refined, replaced, thus gradually working down toward the foot of the precipitation box. By the time that the foot of the box was reached, the cathodes at the head were again ready for refining. The total time of "cleaning up" a precipitation box was from 25 to 30 days. Consequently the operations of cleaning up and refining were going on almost continually.

The solution in the acid refining box was circulated by a lead air-lift. The interval between "clean-ups" of the refining box varied from 15 to 25 days, depending upon the quantity of copper which accumulated at the bottom of the cell.

The copper capacity bore a definite ratio to that of the anode compartments, so that when the former was full the latter was about three-quarters filled. By this time the twill sides of the receptacle were so weakened by the acid that they required replacement.

When it was desired to "clean up" the refining box, the acid electrolyte was siphoned into a storage tank and the anode receptacles were raised and allowed to drain over the refining box. They were then placed in an upright position upon a washing board supported above a tank provided with a filter bottom, the twill was cut down the sides, removed, and the gold slime washed into the tank. The wooden frames were well scrubbed and the twill washed over the same tank, after which it was burned in a dryer. When thoroughly drained, the gold slime was removed from the tank, dried and united with the ashes from the twill.

After mixture with the proper fluxes it was melted in graphite crucibles heated in an oil-fired furnace. The buttons resulting from the preliminary melts were combined, remelted and cast into bars 700 to 800 fine for shipment.

The copper slime was flushed through 1½ in. (4 cm.) holes bored in the side of each compartment 1 in. (2.5 cm.) above the bottom into a cement launder in the floor which conveyed the slime to a tank outside the building provided with a filter bottom. After draining and drying it was sampled and boxed for shipment. The dried copper precipitate contained 84 to 87 per cent metallic copper and 1.82 to 3.72 oz. (53 to 108.5 g) gold per ton. The total time required for a clean-up was 7 hr. A number of years ago, when this system of refining was in operation, the net returns from the copper more than paid all the expense of refining, melting the gold and shipping the copper.

Practice at Virginia City, Nevada

In the installation of the electrolytic precipitation plant at Virginia City, Nevada, Messrs. Charles Butters & Co., Ltd., had the benefit of the experience gained at the plants previously installed on the Rand, South Africa, at Minas Prietas, Mexico, and at San Sebastian, Salvador. This resulted in several quite important improvements.

Originally there were nine boxes, similar to that shown in detail in Fig. 5, the plan being to use three of these boxes for precipitating copper from a preliminary wash by sulphurous acid, which, when the plant first began operations, was intended to precede cyanide treatment. The other six boxes were to be used for precipitating gold and silver, together with any remaining copper from the cyanide solutions.

The preliminary treatment with sulphurous acid was finally abandoned and direct cyanidation practiced.

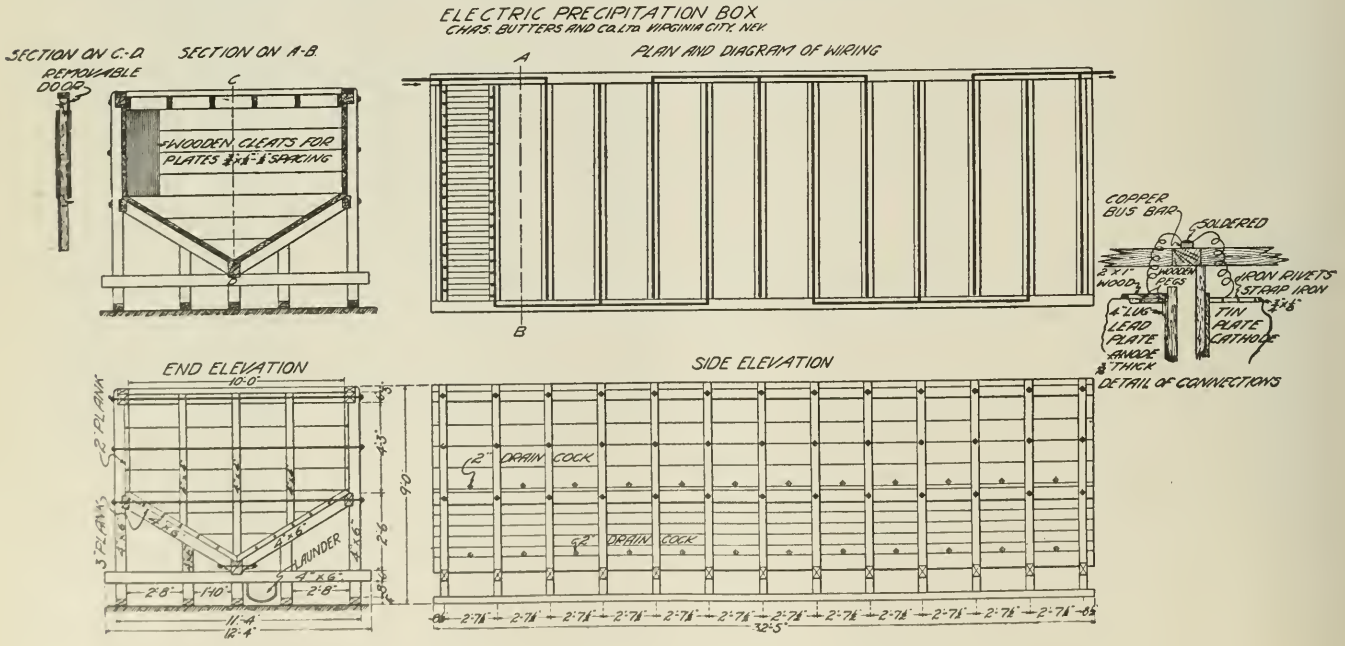


FIG. 5—PRACTICE AT VIRGINIA CITY, NEVADA

The precipitation practice finally evolved for the cyanide solution was to use four of the boxes in pairs of two arranged in tandem, the solution issuing from the first set of boxes passing through the second set. As at San Sebastian, electrolytic precipitation was followed by zinc shaving. The zinc box was improvised by placing screens in the bottoms of a number of the compartments of two of the discarded electrolytic boxes.

At Minas Prietas the method of handling the precipitate was rather crude, as a part of the cathodes and anodes had to be removed to give access to the bottom of the boxes during the "clean-up." At Virginia City this feature of the process was greatly improved by constructing the precipitating boxes with hopper bottoms. In each compartment where one of the sloping sides of the hopper joined the vertical side of the box was located a valve through which the bulk of the solution contained in the box could be drawn prior to sluicing out the precipitate. At the apex of the hopper in each compartment was located another valve through which the slime could be sluiced to a launder which conveyed it to a small concrete tank equipped with a mechanical agitator, whence it was pumped by a centrifugal pump into an ordinary distance-frame and plate type of filter press. After drying, the precipitate was sampled and shipped to the Selby Smelting Company. Later a refinery was built.

The precipitate, after retorting to recover mercury, and after the addition of the proper admixture of fluxes, was melted in graphite crucibles heated in specially designed tilting furnaces.

With the arrangement described above it was not necessary to disturb the anodes or cathodes when cleaning up.

Each box had twelve large compartments, in which were suspended 18 peroxidized sheet-lead anodes ⅛ in. (0.32 cm.) thick, 25 in. (63 cm.) wide and 48 in. (120 cm.) long, and 18 tin-plate cathodes of the same size. Sheet aluminum cathodes were also tried.

Later, an anode composed of lead rods, detail drawing of which is shown in Fig. 6, was used. The advantage of this anode was that it could be made locally from scrap lead or old anodes. The Wood dynamos, each giving 500 amp. at 50 volts, and direct connected to an induction motor, furnished the current.

The character of the ore treated at this plant varied greatly. Originally it was built to treat a large accumulation of tailing which had resulted from the treatment of Comstock ores by pan-amalgamation. Later Comstock ore and concentrator tailing, and ore from the Tonopah district of Nevada, were treated. The treatment of outside ore began before the exhaustion of the tailing, so that at times there was a varying mixture of tailing and ore treated.

The pan-amalgamation tailing had been re-treated a number of times by the same process and was, therefore, very low grade. It contained copper, mercury and chlorides as a result of the chemicals added during pan-amalgamation.

The tonnage and metal content of the solution varied considerably, but the following is an average of the results obtained over a considerable period when treating pan-amalgamation tailing exclusively, and precipitating 474 to 668 tons of solution daily. There was no distinction made between the solution originating from the sand and slime treatment, the two being combined for precipitation.

The average content of the head solution per ton was: Gold, 0.033 oz. (0.97 g.); silver, 0.78 oz. (22.7 g.); no record of copper determinations; cyanide, 0.046 per cent; protective alkali, 6 points. The tail solution from the electrolytic box contained: Gold, 0.01 oz. (0.29 g.); silver, 0.22 oz. (6.4 g.); cyanide, 0.066 per cent; protective alkali, 4 points. The zinc-box tails contained: Gold, 0.003 oz. (0.09 g.); silver, 0.03 oz. (0.88 g.).

The current density was 0.245 amp. per square foot (2.7 per sq. m.) of anode surface. The voltage across the anodes and cathodes in each compartment was 3.1.

The average content of the head solution when treating a mixture of Tonopah ore and pan-amalgamation tailing was: Gold, 0.055 oz. (1.61 g.); silver, 3.15 oz. (91.9 g.); cyanide, 0.18 per cent; protective alkali, 10 points. The tail solution from the electrolytic boxes, when precipitating 432 tons per 24 hr., contained: Gold, 0.02 oz. (0.58 g.); silver, 0.60 oz. (17.5 g.); cyanide, 0.18 per cent; protective alkali, 10 points.

The current density was 0.245 amp. per square foot (2.7 per sq. m.) of anode surface. The voltage across the anodes and cathodes in each compartment was between 3.1 and 3.2. Four lots of precipitate contained

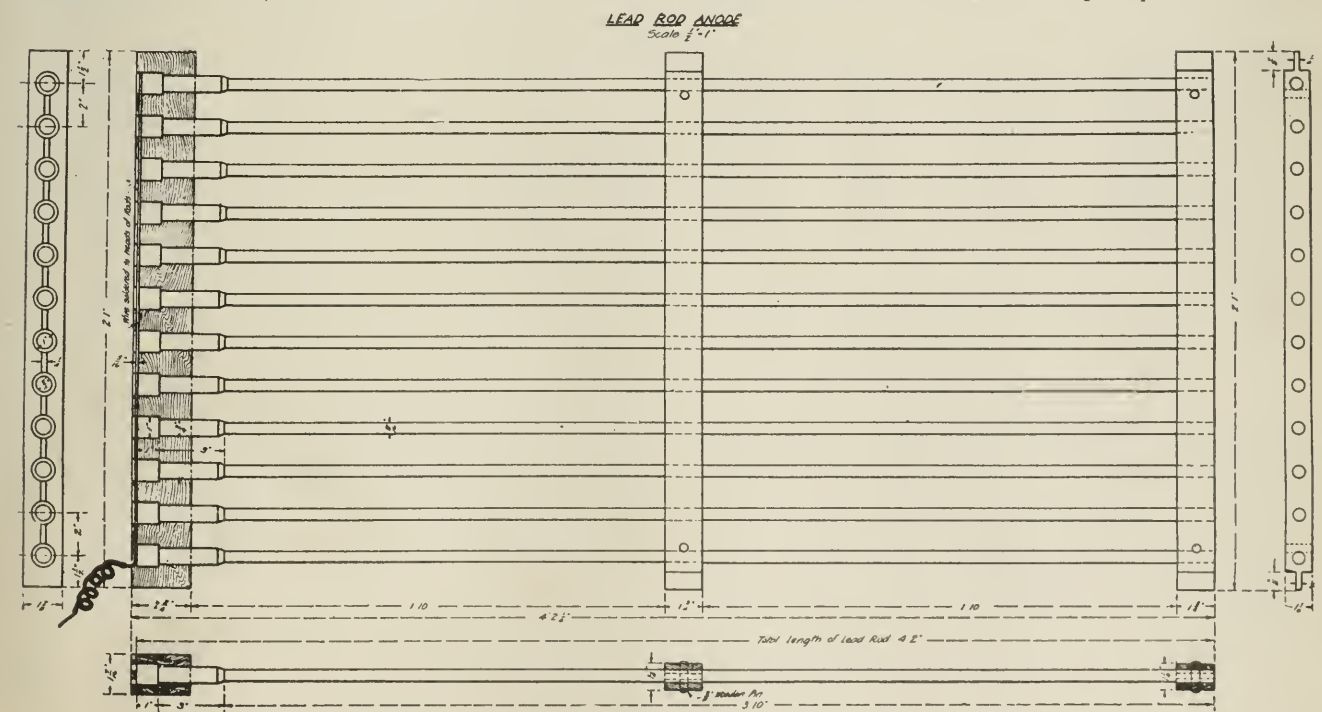


FIG. 6—LEAD ROD ANODE

the percentages of gold, silver and copper, given in Table I.

Table I

	Per Cent		
	Gold	Silver	Copper
A	0.23	9.60	26.60
B	0.23	8.49	29.25
C	0.29	9.99	31.40
D	0.27	7.97	20.10

Table II shows the results obtained in one of the boxes when the conditions of tonnage precipitated, current density, voltage, etc., were the same as those given above.

Table II
(Multiply figures by 29.17 to get grams per metric ton)

	Assay of Solution		Amount Precipitated	
	Silver, Oz.	Gold, Oz.	Silver, Oz.	Gold, Oz.
Solution entering electrolytic box	2.164	0.0403	.....	.....
Solution leaving:				
1st compartment	2.049	0.0405	0.115	0 0
2d compartment	1.756	0.0335	0.293	0.068
3d compartment	1.751	0.0335	0.005	0.0
4th compartment	1.669	0.0310	0.082	0.0025
5th compartment	1.418	0.0265	0.251	0.0045
6th compartment	1.427	0.0275	0.0	0.0
7th compartment	1.271	0.0240	0.156	0.0035
8th compartment	1.193	0.0215	0.078	0.0025
9th compartment	1.124	0.0205	0.069	0.0010
10th compartment	1.022	0.0175	0.102	0 0030
11th compartment	0.886	0.0140	0.136	0.0035
12th compartment	0.824	0.0105	0 062	0.0035
Solution leaving:				
1st zinc	0.417	0.0075	0 407	0.0030
2d zinc	0.225	0.0045	0.192	0.0030
3d zinc	0.048	0.0015	0.177	0.0030

Table III shows the composition in gold and silver deposit, as determined by corrected assay of the cathode deposits in the various compartments of the precipitation equipment when treating exclusively Tonopah ore.

Table III

	Percentage, Silver	Percentage, Gold	Percentage Base Metals and Other Impurities, by Difference
1st electrolytic compartment	87.69	1 93	10.33
2d electrolytic compartment	88.38	1.98	9.64
3d electrolytic compartment	80.02	1.82	18.16
4th electrolytic compartment	81.43	1.89	16 68
5th electrolytic compartment	77.95	1.77	20 28
6th electrolytic compartment	77.50	1 81	20.69
7th electrolytic compartment	67.09	1.48	31 43
8th electrolytic compartment	69.71	1.58	28.71
9th electrolytic compartment	58.33	1.37	40.30
10th electrolytic compartment	62.39	1.41	36.20
11th electrolytic compartment	55.72	1 25	43.03
12th electrolytic compartment	49.96	1.12	48 92
1st zinc compartment	59.38	1 37	39.25
2d zinc compartment	46.20	1 03	52.77

In the case of the electrolytic box, each sample was taken directly from the surface of the cathode.

Practice at El Rayo, Mexico

The equipment installed at El Rayo followed rather closely the lines of that used at San Sebastian, Salvador, and consisted of one wooden box 10 ft. (3 m.) wide by 20 ft. (6 m.) long, 4 ft. (1.2 m.) deep on one side and 5 ft. (1.5 m.) deep on the other, with the usual arrangement of wide and narrow compartments. In each of the seven wide compartments were installed 25 sheet-lead anodes, 20 in. (50 cm.) by 40 in. (100 cm.) and 1/8 in. (0.37 cm.) thick. Alternating with the sheet-lead anodes, there were 24 sheet-copper cathodes, 20 in. (50 cm.) by 40 in. (100 cm.) and 1/32 in. (0.16 cm.) thick. Electrical connection of the anodes and cathodes to the bus bars was made by means of lead plugs cast onto the plates, to which were soldered copper connecting wires. The current was supplied by a Crocker-Wheeler generator giving 500 amp. to 50 volts.

At the time that this installation was made zinc-dust precipitation of the gold and silver was giving satisfactory results. A change in the character of the ore indicated that trouble might arise through a greatly increased proportion of copper. It was, therefore, planned to continue to precipitate the gold and silver by zinc and depend upon electrolytic precipitation to keep the copper in solution down to a concentration which would not interfere with cyanide treatment. To this end 200 tons of solution, the total flow from the zinc precipitation equipment, was passed through the one electrolytic unit. The intention was to deposit the copper in as pure a state as possible so that it could be marketed directly. Certain difficulties arose in accomplishing this end, and before they were overcome, the proportion of copper in the ore had decreased to a point where it was no longer necessary to use electrolytic precipitation.

The equipment was not dismantled and stood as originally installed until the exigencies of the Mexican revolution caused the management to turn to it in an effort to conserve both cyanide and zinc. In this case the original practice was reversed. The cyanide solution was passed directly from the treatment tanks to the electrolytic precipitation box and from thence to the zinc-dust precipitation equipment. There was an average of 200 tons per day of solution precipitated. The average content of this solution was as stated in Table IV.

Table IV

Simple alkaline cyanide	0.15 per cent
Total cyanide	0.38 per cent
Alkalinity	100 points
Copper	0.12 per cent
Zinc	0.05 per cent
Gold	0.30 oz. (8.8 g.) per ton
Silver	5.00 oz. (146 g.) per ton

Approximately 65 per cent of the gold and silver, 20 per cent of the copper, and a small amount of zinc were precipitated by electrolysis. There was a gain in cyanide strength of about 0.075 per cent, with a considerable decrease in the alkalinity. The current density used was 1.2 amp. per square foot (13.2 per sq. m.) of anode surface. Under these conditions of operation the lead anodes disintegrated very rapidly.

Practice at Nelson, British Columbia

In 1907, Douglas Lay described a modified Siemens-Halske installation in use at the Reliance mill, Nelson, British Columbia. The three wooden containing tanks were 35 ft. (10.5 m.) long, 5 ft. (1.5 m.) wide, and 3 ft. (0.9 m.) deep, inside dimensions. The anodes were No. 10 sheet iron (0.35 cm. thick), 5 ft. 1 in. (153 cm.) by 2 ft. 8 in. (80 cm.), set in saw cuts three inches (7.5 cm.) apart, made in the sides and bottom of the containing tank.

The alternate downward and upward flow of the solution, by which means it was caused to pass uniformly by the anode and cathode surfaces, was attained by setting each alternate anode 1½ in. (4 cm.) off the bottom of the box, the solution passing under these anodes and over those set into the bottom of the box.

The anodes were enclosed in cheesecloth to prevent short circuiting. Connections to the main positive wire, which rested in a groove in the top of one side of the box, was made by means of lead plugs cast in holes bored downward to intersect the top edge of the anodes where they rested in the saw cuts in the side of the box.

The cathodes were sheet lead about 1/40 in. (0.6 mm.) thick, made by a special casting process at the Trail smelter, and of approximately the same area as

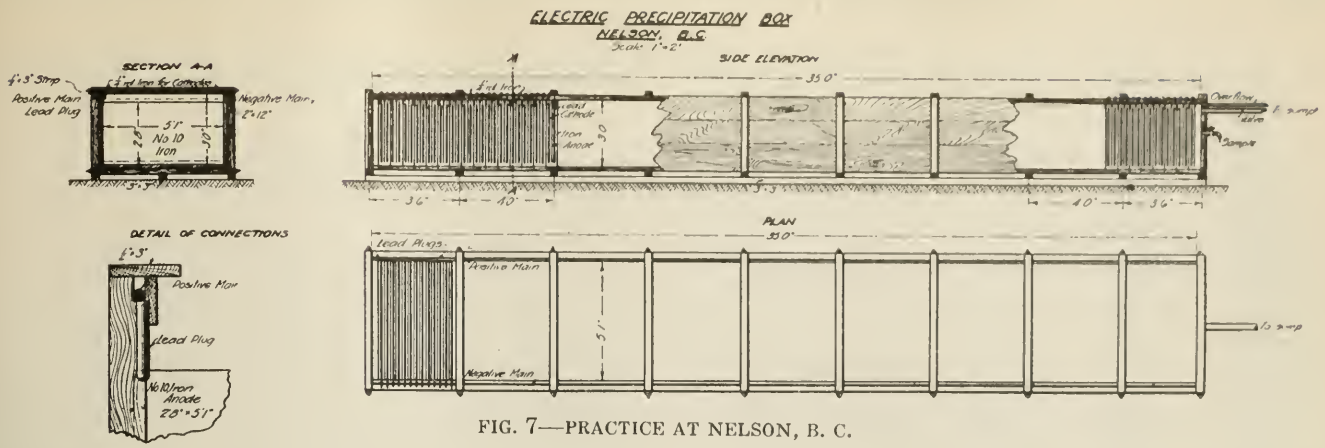


FIG. 7—PRACTICE AT NELSON, B. C.

the anodes. For convenience in handling, each cathode was made up of three sheets, each weighing about 7 lb. (3 kg.), attached to a ¼-in. (0.6 cm.) round iron cross-bar by two strips of roofing tin.

The cathodes previous to being used were dipped momentarily in a slightly acidic solution of zinc chloride to clean them thoroughly. Connection of the cathodes to the main negative wire, which rested on top of the opposite side of the box from the positive main, was made by direct contact of the cross-bar at one end with the negative wire upon which it rested. The other end of the cross-bar rested upon a strip of wood which insulated it from the positive main.

The distance between the anodes and cathodes was therefore 1½ in. (4 cm.). Each box contained approximately a total of 3500 sq. ft. (320 sq. m.) each of anode and cathode surface. A detailed drawing of the whole arrangement is shown in Fig. 7.

The three boxes precipitated 150 tons of solution per 24 hr., resulting from the treatment of 50 tons per day of low-grade gold ore containing 0.20 oz. (5.8 g.) gold ($4.00) per ton. The solutions precipitated were kept at 70 deg. Fahr. (21 deg. C.). A low current density of 0.02 to 0.03 amp. per square foot (0.22 to 0.33 per sq. m.) of cathode surface was used. The voltage across the anodes and cathodes was 4 to 5.

Accurate figures are not available for the composition of the head solution precipitated, but the following are reasonably accurate estimates: Gold, 0.06 oz. (1.75 g.) ($1.20) per ton; cyanide, 0.01 to 0.05 per cent, and protective alkalinity, 0.03 per cent lime. The tail solution contained from a trace to a few cents in gold per ton.

When protective alkali was present there was no loss of cyanide in passing through the precipitation box, but when there was no protective alkali about 30 per cent of the cyanide was decomposed by the current. Presence of sufficient alkali also caused the iron dissolved at the anode to separate as ferric hydroxide, instead of the Prussian blue formed when there is insufficient alkali.

In this installation a special arrangement was made to run off the ferric hydroxide which collected on the surface of the solution, by shutting off the regular outflow and allowing the solution to rise above the tops of the high anodes and overflow momentarily from an auxiliary outflow carrying with it the ferric hydroxide. This operation required but two or three minutes upon each shift.

Anodes

Iron anodes were used with the Siemens-Halske process in South Africa, but lead, with a few exceptions, has been used in American practice. Various other anode materials have been tried but, everything considered, lead is the most satisfactory. One important advantage that lead has over many other anode materials is that it has a certain salvage value after it has served its useful life as an anode. It has been used both plain and peroxidized, but in general the peroxidized anodes have had the longest life.

Many investigators have reported certain anodes as being satisfactory when used in cyanide solutions, but these tests carried on in a small way have always covered entirely too short a period of time. The fact that an anode will stand up for two or three days of continuous operation in no way signifies that it will be satisfactory for a period of operation sufficiently long to make its use commercially economical.

Experiments with Acheson graphite have been most disappointing, notwithstanding the favorable reports made by other investigators who have tried out this material in a small way for short periods of time. The graphite anodes gradually become mushy and soft, and finally are useless. The reason for the failure of the graphite anode is not clear, but at one time I thought that it was due to the disintegration of the binding material used in the original carbon plates from which the graphite plates were made. In other words, the graphite resulting from the carbonaceous binding material of the original carbon plate does not appear to form a strong union with that resulting from the carbon proper of the plate.

The sheet-lead anodes are made up as shown in Fig. 8. The sheets of lead, after cutting to the desired size, are thoroughly cleaned and in one corner or on the two opposite corners of the short dimension of the sheet is cast a special connecting lug, ½ in. (1.3 cm.) in diameter by 4 in. (10 cm.) long, by means of a special iron mold which firmly clasps the plate at the point where the lug is to be attached. The lugs are cast from lead to which has been added a small amount of tin, to lower its melting point. The temperature of the lead used in casting the lug should be such that does not melt through the lead sheet, but still is sufficiently hot to form a thorough union with the lead sheet. A tongued wooden supporting strip is attached to the top of the plate by means of wooden pins.

The lead-rod anodes are made up as shown in Fig. 6. Lead rods of the form shown in the drawing are cast in special iron molds, observing the usual precautions for preventing the oxidation of lead during melting and the obtaining of a clean, smooth casting free from holes or spongy spots. Twelve of these rods supported in strips of pine drilled to receive them at the bottom, at the center and at the top, comprise an anode.

The bottom and center strips are 1.75 in. (4.4 cm.) by 1.25 in. (3.2 cm.), and are kept from shifting by means of wooden pins which engage the two outside rods. These also serve to prevent short-circuiting of the tinplate cathodes, which have a strong tendency to buckle.

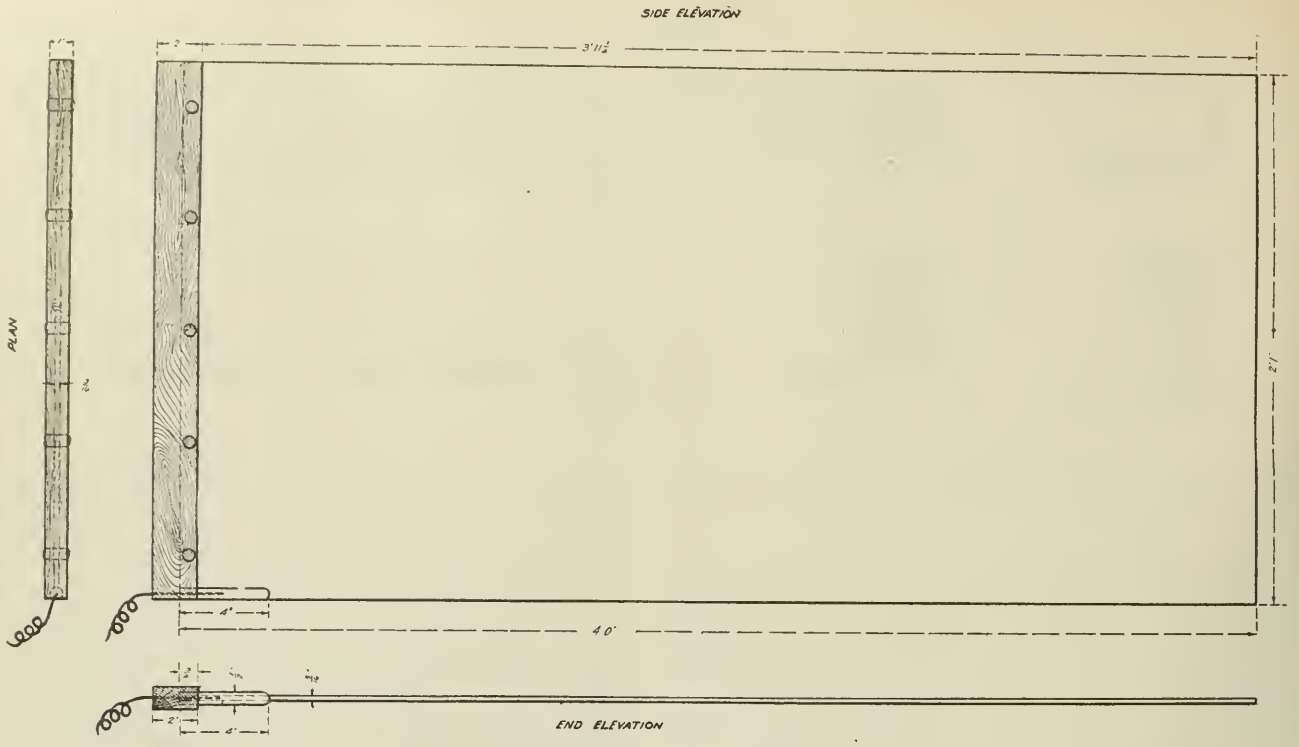


FIG. 8—LEAD PLATE ANODE

The top strip, 2¾ x 1⅞ in. (7 x 4.7 cm.), is counterbored to receive the large ends of the rods and supports the whole weight of the anode.

Electrical connection to the individual rods is made by soldering to them a No. 10 (2.5 mm. diameter) copper wire, which rests in a groove at the top of the strip. The continuation of this wire serves as the means of connecting the anode to the bus-bar.

The method of peroxidizing the anodes varied somewhat at the different plants. This operation was performed in a separate cell where a few anodes at a time were treated. The first step was to clean and brighten thoroughly the surface of the lead with a scratch brush.

At Minas Prietas a 1 per cent potassium permanganate solution was used and a current density of 1 amp. per square foot (11 per sq. m.). The time was 1 hr. or longer. During the operation the strength of the solution was frequently tested with a standard solution of ferrous sulphate, fresh permanganate being added to keep the solution as near 1 per cent as possible.

At San Sebastian various combinations were tried, but the practice that met with the most favor was to use an electrolyte containing 1 per cent of potassium permanganate, 2 per cent of sulphuric acid and a current density of 2½ amp. per square foot (27.5 per sq. m.). The time of treatment was 6 hr.

In passing, it is well to mention that it has been found in certain of the electrochemical industries that a denser and more satisfactory coating of the peroxide is formed if the operation is performed in an alkaline solution.

At Virginia City the peroxidized lead anodes had a life of about one year. At San Sebastian, on account of the higher current density the life was 8 to 12 months. At Minas Prietas the life was in some cases considerably over a year.

Cathodes

The lead-plate cathodes used at San Sebastian were constructed similar to the anodes, except that the sheet lead used was thinner.

An interesting feature of the lead cathodes used at the Reliance mill was that they were not ordinary rolled sheet lead, as had been previously used elsewhere for both anodes and cathodes, but were plates cast upon an inclined machine at the Trail smelter. The simplicity of the arrangement will be apparent from the drawing shown in Fig. 11. It was said that one man could make 500 cathodes in a shift.

The tin-plate cathode was made from medium-weight tin-plate, as shown in detail in Fig. 9. A piece of strap iron ¾ x ⅛ in. (1.9 x 0.3 cm.), whose length was the same as the width of the plate, was riveted to the top. The connecting wire was introduced between the plate and strap iron in such a manner that one of the rivets clamped it firmly in place.

Fig. 10 shows the tools used in removing the portion of the deposited metals which adhered to the cathodes. The double brush was used at intervals for removing the slightly adherent deposit. The manner of using was to set it over the cathode so that a brush was bearing on either side of the cathode, when the whole tool was pressed downward until the brushes had reached the bottom of the plate; this operation was repeated until the whole surface of the plate had been covered. When it was desired to make a complete clean-up, especially if the plates were old, it was necessary to remove them entirely from the box and scrape them with the triangular scraper, shown in Fig. 10.

By-Products of Electrolytic Precipitation

The by-products which appear to be inevitably produced during electrolytic precipitation and which are particularly troublesome when treating gold ores on account of the greater value of the metal involved, have always formed a most serious problem.

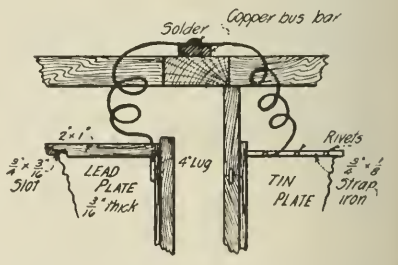


FIG. 8A—DETAIL OF CONNECTIONS (SEE FIG. 8)

In the Siemens-Halske process the Prussian blue, formed as a re-

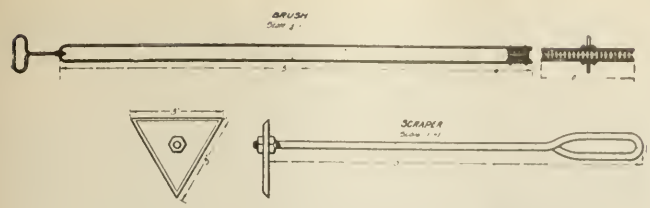


FIG. 10—TOOLS FOR CLEANING CATHODES

sult of the attack on the iron anodes, had to be subjected to special treatment for the recovery of the cyanide and gold which it contained. The disadvantages arising through the separation of calcium salts, which deposited upon the anodes and cathodes and in the bottom of the box, was early noted in the application of the process. It has been variously estimated that from 0.6 to 25 per cent of the gold had to be recovered from the by-products in the Siemens-Halske process.

At Minas Prietas, the precipitation of calcium salts was especially troublesome, and owing to the method of operating in which the non-coherent deposit of the metals was collected in the bottoms of the boxes, all of this eventually became intermingled with the precipitate. At this time the calcium salts, chiefly the carbonate, formed a large proportion of the precipitate.

TABLE V.—ANALYSIS OF LIME DEPOSIT

	Per Cent
Moisture	0.275
Loss upon ignition	6.060
Calcium oxide	41.580
Carbonic acid	31.120
Lead metallic	13.530
Iron oxide	0.540
Copper metallic	0.750
Sulphuric acid	4.400
Chlorine	0.670
Vanadium	0.095
Silver	0 126
Gold	0.003
	99.149

This made the precipitate more difficult and costly to smelt. In Table V is given a typical analysis of the lime deposit at the plant.

Lowered current density lessens the formation of the lime precipitate. In the course of time the lead anodes disintegrated to the extent that they had to be discarded. At first these were shipped to lead smelters, but later they were remelted locally, and after the separation of the dross, which had to be shipped to the smelter, were cast into slabs which were rolled by a special set of rolls into sheets which were used in making new anodes.

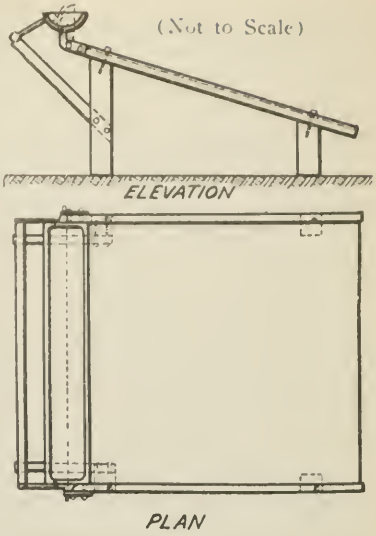


FIG. 11—CASTING MACHINE FOR LEAD PLATE CATHODES, TRAIL SMELTER, B. C.

At San Sebastian, where the gold and copper formed a coherent deposit upon the cathodes, it was possible to keep the deposit which accumulated at the bottom of the box separate from the deposited metals. However, the gold contained in this material was considerable, and at one time, when a considerable amount of it had been allowed to accumulate, it represented a great deal of value. The material more directly resulting from the disintegration of the anodes contained:

Lead	53 7 to 57.1 per cent
Copper	3.1 to 4.7 per cent
Gold	0 031 to 0.154 per cent

The fine material, or "lime" as it was termed, contained:

Silica	8 to 10 per cent
Alumina	22 to 28 per cent
Calcium oxide	15 to 21 per cent
Lead	Not determined
Copper	5.9 to 6.9 per cent
Gold	0.322 to 0.363 per cent

A small blast furnace and other refining equipment was installed for treating the by-products, but on ac-

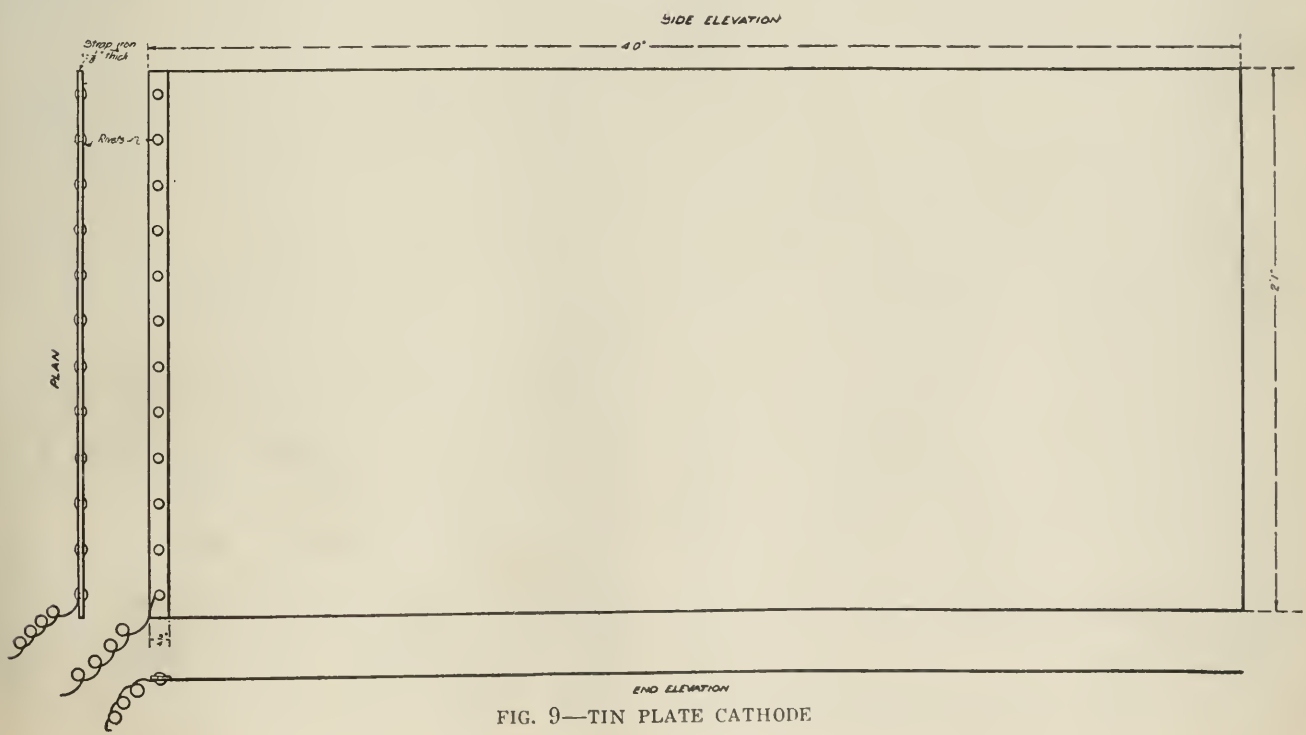


FIG. 9—TIN PLATE CATHODE

count of the high cost of coke and other supplies and the lack of skilled labor, it was generally found more economical to ship this material to smelters in the United States. No attempt was made at this plant to reclaim the anodes.

At Virginia City the conditions were much the same as at Minas Prietas. A much lower grade precipitate was invariably obtained from the electrolytic boxes than from the zinc boxes on account of the calcium precipitate. At one time, as the result of careful sampling and assaying, it was estimated that the anodes contained about 10,000 ounces of silver. This came about by reason of the fact that the solutions contained chlorine. The source of this in the tailing was the salt which had been added during pan-amalgamation and, in the Tonopah ore, was due to the occurrence of part of the silver as chloride. The presence of the silver as chloride in the anodes was proved by solution in ammonia and the regular qualitative tests. In the earlier operation the disintegrated anodes were shipped to the smelter; but later it was found that by careful heating in suitable pots the greater part of the metallic lead could be liquated, leaving most of the gold and silver in the dross. The dross was shipped to the smelter and the lead cast into rods which were mounted in wooden supports and used as anodes.

Cost of Installation and Operation of Electrolytic Precipitation Plants

The cost of the six electrolytic precipitation boxes at Minas Prietas, Mex., was as stated in Table VI.

Table VI.—Cost at Minas Prietas

Box construction	$10,000.00
Dynamos	3,000.00
Lead anodes	4,455.00
Tin plate cathodes	300.00
Wiring, switchboards and instruments	1,000.00
Labor	1,000.00
Incidentals	250.00
Total for six boxes	$20,005.00

At Virginia City, Nev., U. S. A., the cost of six standard boxes was as stated in Table VII.

Table VII.—Cost at Virginia City

Box construction	$6,000.00
Dynamos	4,075.00
Lead anodes	4,080.00
Aluminum cathodes	*1,598.00
Wiring, switchboards and instruments	1,000.00
Labor	1,500.00
Incidentals	250.00
Total for six boxes	$18,503.00

*N. B.—Tin plate cathodes also used.

W. H. Wood, in 1899, compiled comparative figures of the cost of installation on the Rand, South Africa, of precipitation equipment for operating the Siemens-Halske electrolytic and the zinc-shaving lead-couple processes for a plant crushing 500 tons of ore per day. These are given in Table VIII.

Table VIII.—Comparative Costs

	Zinc Lead Precipitation	Electrolytic Precipitation
Extractor house space	$792.18	$2,551.50
Concrete floor	296.46	928.26
Wooden containing boxes	558.90	3,159.00
Platforms	.....	703.00
Piping	109.35	257.58
Zinc (Cut.)?	299.62	.....
Dynamo	.....	1,083.78
Lead cathodes	.....	414.32
Frames for cathodes	.....	218.70
Iron anodes	.....	1,603.80
Anode bags	.....	148.23
Wiring and proportion of power	.....	1,044.90
Proportion of general charges	71.93	424.04
	$2128.44	$12,537.11

The only costs available for electrolytic precipitation are those given in Table IX, which are the average for six years' operation of the Minas Prietas plant.

Table IX.—Electrolytic Precipitation Costs at Minas Prietas

Power	$0.083
Labor	0.037
Supplies	0.031
Depreciation	0.04
Total per ton of ore	$0.191

It will be noted that both the cost of installation and operation of electrolytic precipitation is higher than zinc precipitation.

In the preparation of this paper I am indebted to the following gentlemen: Mr. Charles Butters for information upon electrolytic precipitation obtained through visits to his plants during the time that they were in operation, as well as through personal communications; E. M. Hamilton for information contained in his paper upon the practice at Minas Prietas, also personal communications; Charles P. Richmond for information contained in his paper upon the practice at San Sebastian, also personal communications; James Colbath for the details of the El Rayo practice; Richard Snell, H. Bulmer and Robert Wisnom for certain details of Virginia City practice; Douglas Lay for information contained in his paper upon the practice at the Reliance mill, and M. F. Perry for the detailed costs of installation and operation of the Minas Prietas plant. I have freely used the information contained in von Gernet's first paper upon the Siemens-Halske process, as well as that contained in other papers upon the subject which have been published at various times in the Proceedings of the Chemical and Metallurgical Society of South Africa. I also wish to acknowledge the faithful and painstaking work of my assistant, Mr. K. Pyle, in the preparation of the drawings.

Palo Alto, Cal.

Potash.—The American Potash Company of Long Beach, Cal., has been purchased by the American Produce Company, who will operate the plant for producing potash and cellulose from kelp on a large scale.

Stamp Mills.—The Allis-Chalmers Co. of Milwaukee, Wis., have issued Bulletin 1432-A describing their stamp mills and accessory machinery for free-milling gold ores. This includes specifications for complete ten-stamp and two-stamp mills.

Abrasive Grinding Wheels.—The Abrasive Material Co., Philadelphia, Pa., has sent us its catalog of abrasive grinding wheels, and also pamphlet describing Boro-Carbone, a new abrasive which it has recently placed on the market.

Precious Metals in Colorado.—The total value of the output of gold, silver, copper, lead and zinc in Colorado in 1914 was $33,460,126, according to the annual statement of the U. S. Geological Survey. Of the total, 59 per cent represented gold.

Resistance and Inductance of Wires.—A paper dealing with experimental determinations of the electrical properties of iron and bi-metallic wires used in telephone and transmission work has been issued by the Bureau of Standards as Scientific Paper No. 252. The author is Mr. John M. Miller.

The Johnson Engineering Co., Chicago, Ill., has just shipped to the Detroit Copper Mining Company, Morenci, Ariz., two of its largest diameter Marathon mills, which will do all of the regrinding in a plant of 1800 tons daily capacity. Five of the largest diameter mills were also shipped to the Burro Mountain Copper Company, Tyrone, N. M., for regrinding in the new plant of 3000 tons daily capacity.

Manufacture and Tests of Silica Brick for the Byproduct Coke Oven*

BY KENNETH SEAVER

It is rather gratifying that in the field of the manufacture of refractories, in which, as a whole, foreign practice has surpassed us, the United States stands pre-eminent in the making of silica brick. In some instances European manufacturers have refused point-blank to credit the possibility of making to such specifications as are common with us, until the actual completed shapes were shipped for inspection. But both the manufacturer and consumer in foreign lands are now frankly learning from us, and benefiting by our advanced practice in this field, as is evidenced by the orders placed here and the efforts put forth abroad to come up to the standard of American-made material.

In no metallurgical operation has the employment of silica brick spread with such leaps and bounds as in the building of plants for the carbonization of coal, particularly in the byproduct coke oven. To-day, in practically all types of oven, the structure above the floor level (except the facings) is of silica, while in the recuperative and in some regenerative types, its use is extended to that portion of the oven below the floor as well.

By reason of the fact that there are a number of classes of refractories of higher silica content than the usual so-called fire-clay brick, there is sometimes a misunderstanding as to the class of material referred to as "silica" brick. We here refer only to a brick having a silica content of 94 per cent or more and made usually from quartzite rock with a small percentage of lime as a binder. The term "silica" brick is sometimes rather loosely applied to brick from highly siliceous clays, or to a quartzite refractory of mingled fire-clay and quartz rock; but such products are not considered in this discussion.

Materials

The rock from which practically all high-grade silica brick are made is a true quartzite or metamorphosed sandstone, variously known as ganister, quartz, quartzite, sandstone, silica rock, etc.—the fields of major importance being in the order of their relative importance, those of Pa., Wis., Ala., and Col.

PENNSYLVANIA QUARTZITE

Pennsylvania probably manufacturers from 75 to 85 per cent of all the silica brick made in the United States, almost entirely from the quartzite found in the Medina and Oneida formation. While this formation extends across the State of Pennsylvania reaching into New York State on the north, and Maryland, Virginia and still farther toward the South, the quarries are practically all in Huntingdon and Blair counties, Pennsylvania. It is in this restricted area that the quartzite is at its best. Toward the north and toward the south it becomes softer, is no longer a true quartzite, or is too much impregnated with iron. The rock is also comparatively easily accessible in the counties mentioned, enormous quantities lying loose upon the surface. The particular occurrence of this loose rock has here been brought about by the Juniata River and its tributaries, as they have cut across the formation, wearing away the softer formations beneath, and leaving the Medina overhanging and exposed. In the course of time it has been weathered and broken up by the elements into the bodies of loose rock or "floes," as they are called, which may cover an area of a thousand acres or more. The depth usually varies from three or four to as much as 20 ft. Smaller floes formed in the same way may be found along the flanks of the mountains; but they nowhere compare in size with those formed where the measures have been cut transversely.

This rock is sometimes quarried out of the solid measures; but by far the largest amount used is that taken from the bodies of loose rock, as the latter is not only cheaper to work but is of more uniform quality. The white Medina formation is not composed entirely of quartzite, but is made up principally of sandstone with intermingled strata of quartzite. Thus where the formation has been broken up, the softer sandstones unsuitable for the manufacture of silica brick have tended to weather away and disintegrate, and have left the larger portion of the floes to consist of quartzite. When sandstone is mixed with the quartzite in the floes it is readily detected by its appearance, as it tends to become much more rounded and worn in weathering than does the quartzite, which maintains its sharp, angular edges.

The individual pieces in these floes range in size from those of fist-size to boulders weighing many tons. Probably 50 per cent of the rock occurs in pieces weighing more than 500 lb. The largest floes are found at the gorges of the Juniata River near the towns of Mount Union, Mapleton, Point View, Lewiston, etc.

It is interesting to note that the Oriskany sandstone, extensively used as glass sand, is found in close proximity to the Medina and that although exceedingly pure in its composition, its softness renders it unsuitable for high-grade silica brick. It consists of a mass of minute quartz grains loosely held together, and often so friable that it can be easily worn away by the hands. On the other hand, the Medina quartzite consists of quartz crystals cemented in a mixture of the same composition and of equal hardness with the crystals. The difference in the two types of rock when ground to sufficient fineness for the manufacture of brick is obvious. The harder stone gives splintery, angular fragments; the other, rounded grains. Experience shows that a hard rock like the Medina is required for a physically strong silica brick.

The white Medina which occurs in southern Pennsylvania near the town of Hyndman is there prominent and of a pure variety, but by no means as hard as the quartzite of Huntingdon County.

A representative analysis of the Pennsylvania quartzite is as follows:

	Per Cent
Silica (SiO_2)	97.80
Alumina (Al_2O_3)	0.90
Iron peroxide (Fe_2O_3)	0.85
Lime (CaO)	0.10
Magnesia (MgO)	0.15
Alkalies	0.40
	100.00

WISCONSIN QUARTZITE

This rock, much used in the manufacture of silica brick in the vicinity of Chicago, is known as the Baraboo quartzite from the town of that name where these measures appear, and near which are the quarries. The rock occurs in high cliffs throughout this region and is especially prominent around Devil's Lake. Here glacial action has excavated a deep, broad valley in the quartzite formation bounded on each side by cliffs several hundred feet in height. Their bases are covered with the loose rock split from the parent ledges. While the fragments are much larger as a whole than the weathered Medina of Pennsylvania, the quality by no means compares with the latter. Practically all the stone used in brick making is here quarried from the solid measures.

The marked peculiarity of this rock, as compared with the Pennsylvania quartzite, is its reddish color, which ranges from a light pink through a dark purplish red

*A paper read before the San Francisco meeting of the American Institute of Mining Engineers, September, 1915.

almost to black. It is often as red as the red Medina of Pennsylvania, a sandstone wholly unsuited for brick making. While the coloring of the Baraboo quartzite is due to iron, it is yet an exceedingly pure rock. The quartzite often becomes lighter in color as the quarry works in from the face of the cliff; but it is the exception to find white rock.

This Baraboo quartzite, estimated as some 4000 to 5000 ft. in thickness, is a metamorphosed sandstone, the sedimentary origin of which is indicated by its parallel bedding planes, by ripple marks, etc. Layers of quartzite are often separated by beds of quartz schist varying from a few inches to several feet in thickness. This schistose structure is due to the admixture during deposition of clayey material, which in the subsequent folding and bending of the rock has developed a slablike or schistose structure.

The United States Geological Survey explains the formation of the quartzite as due to the enlargement of the original quartz grains and to the deposition of interstitial quartz. It was the latter that carried the iron oxide, giving the characteristic color to the rock. Regardless of its color, the formation throughout shows the physical characteristics of hardness and strength, and the splintered and angular fracture in crushing, identical with the Medina quartzite of Pennsylvania. A typical analysis follows:

	Per Cent
Silica (SiO_2)	97.15
Alumina (Al_2O_3)	1.00
Iron peroxide (Fe_2O_3)	1.05
Lime (CaO)	0.10
Magnesia (MgO)	0.25
Alkalies	0.10
	99.65

ALABAMA QUARTZITE

The material used in silica brick manufactured in Birmingham, Ala., is found in the eastern part of that State. It is bluish white, and as hard and crystalline as the Wisconsin quartzite; average analyses show it to be equally pure. It occurs in lenses of varying size, in a sandstone formation. It is probably a quartzite formed by a leaching out of impurities from the parent rock followed by a crystal growth and additional deposit of silica from circulating waters. A typical analysis follows:

	Per Cent
Silica (SiO_2)	97.70
Alumina (Al_2O_3)	0.96
Iron oxide (Fe_2O_3)	0.80
Lime (CaO)	0.05
Magnesia (MgO)	0.30
Alkalies	0.31
	100.12

In Colorado and Montana both quartzite and sandstone are used to some extent in the manufacture of silica brick.

Method of Manufacture

QUARRYING

The methods of quarrying as necessitated by the mode of occurrence of the quartzite are so obvious as to need no description. The only point which is of importance is that of adequate supervision in the selection of the rock, whether it be from floes or from the solid measures. Whatever the location or occurrence of the rock, such care is essential; the easiest way to keep bad rock out of the brick is never to let it reach the plant.

GRINDING

After the rock broken to one-man size is received at the rear of the brick plant, it is put through some of the familiar types of crusher, which reduces it to practically the size of a 1- to 2-in. ring. It is then elevated to storage bins from which it may be fed direct

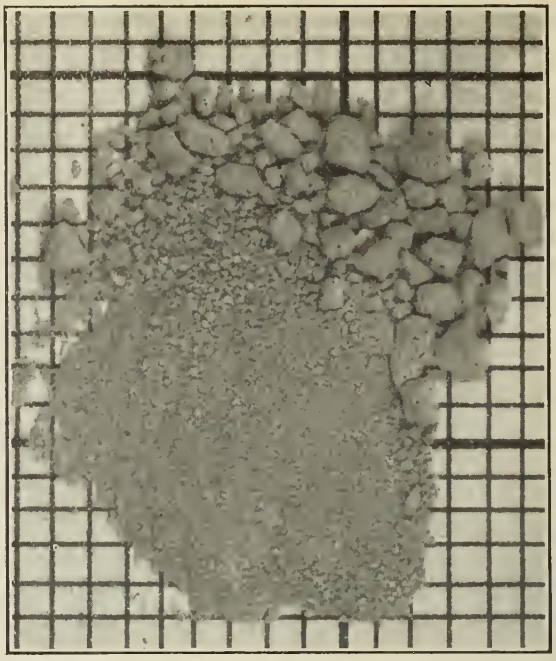


FIG. 1—MATERIAL FROM UNBURNED AVERAGE STANDARD 9-IN. BRICK

in definitely weighed quantities to the wet pans for grinding.

Into the wet pans, as the grinding proceeds, 2 per cent of lime, by weight, is introduced as milk of lime. When the brick is burned, the lime in combination with the other elements in the mass serves to give the necessary bond or physical strength. The quality of the lime has no small effect upon the resulting characteristics of the brick. The effect of an increase in lime from 2 to 3 per cent is not marked; but such as it is, renders the brick less able to withstand abrasion, as is indicated by rattler tests. The decrease in strength on further additions of lime up to 7 per cent is progressive, and becomes more and more evident with each addition. There is, on the other hand, a decrease in strength at 1.5 per cent of lime, and a marked weakness and friability as the amount of lime is still further diminished. As regards ultimate refractoriness, no marked effect is noticeable upon increasing the lime addition up to 3 per cent. From that point on the effect is clear in a lowering of the fusing point.

The fineness to which the charge in the wet pan is to be ground depends upon the nature of the brick to be made from it and is, of course, controlled by the time during which the charge is allowed to remain in the pan. In general, one charge, containing material for 200 brick, will be ground by approximately four pans per hour for standard 9-in. brick, while to obtain the fineness requisite for the intricate and difficult shape-work necessary in byproduct coke-oven construction, but two pans per hour may be possible. The rock is exceedingly hard, and a comparatively slight increase in the fineness of grind is accompanied by a seemingly disproportionate lowering of grinding capacity, and increase in wear on the pans.

The actual differences in grind, however, are much smaller than is often imagined. Figs. 1 and 2 are photomicrographs with a magnification of 2 diameters, the ground material showing on a background of cross-section paper with 0.1-in. spacing. The specimens are from pieces of green or unburned silica brick, crushed down after drying. Fig. 2 indicates typical fine-ground shape-work, while Fig. 1 is that of average standard

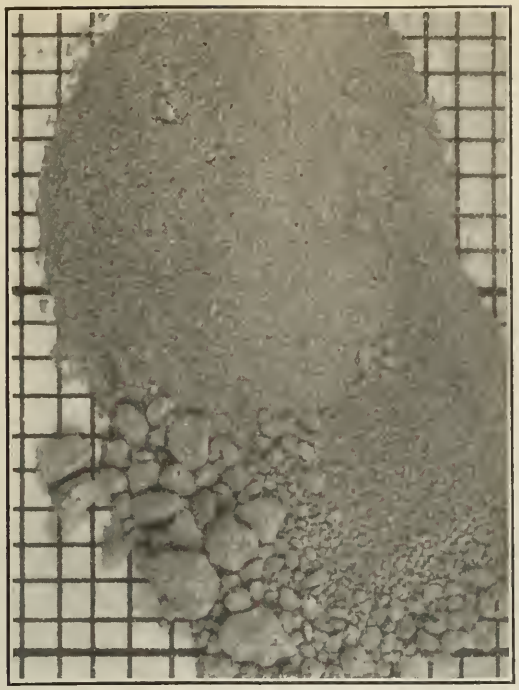


FIG. 2—SAMPLE SHOWING MATERIAL USED IN TYPICAL FINE-GROUND SHAPE WORK

9-in. brick. The difference between these is also shown in the screen analysis of the two.

It will be plainly apparent from the photomicrographs that the difference lies not so much in the actual size of either the coarse or the fine grains as in the relative proportion of fines. In the finer-ground brick the larger proportion of these is clearly evident. There can be no question that the general effect of increasing the fineness of grind is to improve the abrasive resistance of the brick, if it is properly burned. In general, the requirements as to grind contained in typical coke-oven specifications have worked no hardship upon the manufacturer; for the present-day standard of workmanship on byproduct oven shapes is such as to "carry its own grind with it," if the expression may be used. To secure the accurate filling out of the shapes, and the clean-cut accuracy everywhere essential, the grind is actually much finer than is requisite to satisfy the usual specifications as to that particular feature.

MOLDING

The ground silica material as ready to mold is of about the consistency of damp sand, but (possibly because of the extreme angularity of its grains) has less flow as it is manipulated. As a consequence, the molds must be filled by pounding with heavy plank beaters covered with metal, and all corners and shapes of irregular outline must be rammed in by hand, much as sand molds are made, but with much heavier blows. Unequal ramming, leaving too great a variation in the density of the green brick, will give unequal expansion in the kiln. It is by no means uncommon to lose hundreds of a new and difficult shape through such fire-cracking. To get proper molding and ramming requires the strictest supervision.

FIG. 3—TYPICAL SECTION OF HOT FLOOR SHOWING COKE-OVEN "GUN" BRICK SHAPES IN PROCESS OF DRYING

The wear on the molds due both to the attrition of the grains and the pounding is exceptionally severe. In view of the extreme accuracy required, steel molds are used exclusively for all high-grade coke-oven work. These molds are often decidedly complicated, and always expensive, as "loose sides" must be used throughout. Ground silica has, as molded, almost no physical strength, and can be taken from the mold only by allowing the sides to come with it, after which the sides are stripped.

After molding, the shapes are placed on pallets, on which the brick are dried either on the steam-heated hot floor or on rack cars in some form of tunnel dryer (Fig. 3). The brick are then ready to be set in the kilns. Although setting is a most important feature in the manufacture will not attempt to discuss it here.

BURNING

The vast majority of silica brick are burned with soft coal in the familiar type of round, down-draft kiln, varying in diameter from 30 ft. upward. Although practice may vary somewhat, and much depends on the size of the kiln, the following schedule of burning may be considered as fairly normal. Assume that the setting is complete and the doors are sealed. Fire is immediately started, and continued slowly and with slight acceleration for from nine to twelve days, during the last two or three of which the final temperature should be practically maintained. The kiln is then held at the required temperature, say a 26 cone (1650 deg. C., or 3002 deg. Fahr.) directly in front of the firebox, for another day, after which the fireboxes may be sealed and allowed to remain thus for approximately 24 hr. more. Cooling will require about as long as the burning proper; but this varies somewhat with atmospheric conditions.

It is obviously difficult to take temperatures in the interior portions of the kiln except by cones; but there are often most perplexing variations in this method. There are apparently certain conditions in the atmosphere of a burning silica kiln which alter the readings of standard cones to no small degree. Cones which give concordant results, week in and week out, in clay kilns are often decidedly erratic in registering the temperatures of silica kilns. It is by no means uncommon to witness cones of higher number go down, while next to them those lower in the series are either but slightly bent or apparently unaffected.

EFFECT OF BURNING ON COMPOSITION AND EXPANSION

In any discussion of the desirable qualities of silica brick there is frequently expressed the necessity that "all the expansion shall be burned out of them." This brings out the questions: to what is the expansion due; how may it be completely effected if that be possible; and by what means can that result be ascertained.

That the terms used in the discussion may be clear, let it be premised that all silica brick are of course made in molds smaller than the proposed size of the finished or burned brick, and that under the influence of heat a permanent expansion occurs, swelling the

brick from the mold or "green" brick size to the required or "burned" size. It is this expansion occurring during burning that it is desired to accomplish so completely as to preclude further expansion in subsequent use.

Now, in every burned silica brick expansion will occur on heating—a true thermal expansion, identical in its general character with that incident to the heating of practically all bodies. Such thermal or temporary expansion will disappear upon cooling, and being the expression of the coefficient of expansion of the silica it is unavoidable. But it is argued that, if a silica brick is not properly burned, then, upon reheating in actual coke-oven practice, there will be not only a normal thermal expansion but an additional expansion of indeterminate amount which will be permanent. It is essential in the construction of the coke ovens that the expansion, whatever its nature, be as small as possible, and that, whatever it is to be, it be known and adequately cared for.

It will be recalled that the silica brick under consideration is made merely by adding 2 per cent by weight of milk of lime to quartzite rock of the following composition, say:

	Per Cent
Silica (SiO_2)	97.80
Alumina (Al_2O_3)	0.90
Iron peroxide (Fe_2O_3)	0.85
Lime (CaO)	0.10
Magnesia (MgO)	0.15
Alkalies	0.40
	100.20

The representative silica brick produced may be assumed to have the following composition:

	Per Cent
Silica (SiO_2)	96.25
Alumina (Al_2O_3)	0.88
Iron peroxide (Fe_2O_3)	0.79
Lime (CaO)	1.80
Magnesia (MgO)	0.14
Alkalies	0.39
	100.25

What are the changes which occur as the siliceous mass is burned?

Certain of these are obvious, such for instance as the formation of a bond of one or more of the lime-silica compounds such as the meta-silicate CaO, SiO_2 or the ortho-silicate 2CaO, SiO_2. With the exception of the lime present, the peroxide of iron and the alumina, though small in quantity, are the preponderating impurities and there is undoubtedly formed a certain amount of silicate of iron as well as compounds of the lime-alumina series. Whereas the lowest melting point incident to any eutectic of the lime-silica system is 1436 deg. C. (2617 deg. Fahr.) and of the alumina-silica series is 1610 deg. C. (2930 deg. Fahr.), while that of the lime-alumina system is 1400 deg. C. (2552 deg. Fahr.), some of the eutectics of the ternary system CaO, Al_2O_3, SiO_2 melt at approximately 1170 deg. C. (2138 deg. Fahr.) and are thus among the first of the flux compounds resulting.

No less important, though less recognized, changes are occurring in the brick as it is heated. The evidence of the change, regardless of its reason, is easily indicated by the most casual measurement when brick are drawn from the kiln from time to time, as higher temperatures are reached. The final expansion will be very close to 38 in. per foot.

The valuable work done by Day, Shepherd and particularly by Fenner, on the Stability Relations of the Silica Minerals (*American Journal of Science*) give the results in a large field of laboratory experiment, which make possible a fair understanding of what occurs in the actual burning of the silica brick. Fenner's work was to establish among other things the relations between the minerals quartz, tridymite, and cristobalite, all silica minerals and any of which could be converted into any other by appropriate heat treatment. For the purposes of this discussion it is unnecessary to touch upon the alpha and beta phases of these minerals. In substance, the results under the conditions imposed by the experiments were that powdered quartz, if heated, remains quartz until a temperature of 870 deg. C. (1598 deg. Fahr) is reached, at which inversion point there begins a slow change to tridymite. If heat is still applied, there is no further change from tridymite until 1470 deg. C. (2678 deg. Fahr.) is reached, when inversion to the form of cristobalite has its beginning. There is no further change until the cristobalite may melt into a glass. Thus the stable phase of quartz (quartzite rock as applied to silica-brick manufacture) extends to 870 deg. C. (1598 deg. Fahr.). Between 870 deg. C. (1598 deg. Fahr.) and 1470 deg. C. (2678 deg. Fahr.) the stable phase is tridymite, while above 1470 deg. C. (2678 deg. Fahr.) cristobalite is stable.

As a whole it must be carefully noted that the changes from one mineral to another were exceedingly slow, particularly near the inversion points. So slow in fact were the alterations, that the melts were made in a flux of a large excess of sodium tungstate which acted as a flux or catalyzer. The powdered quartz or whatever might be the silica mineral under study was stirred into the molten bath of flux and the platinum container was then treated in a suitable furnace. This flux in no way entered into chemical combination with the silica but only aided and quickened its action, apparently furnishing a fluid medium through which the molecular rearrangement was facilitated. In spite of this, the slowness of the inversion, often requiring many hours, will bear emphasis in drawing conclusions regarding any parallelism between these experiments and the burning of brick.

A particularly noteworthy fact is that in the absence of a flux or catalyzer, the inversion from quartz to tridymite does not occur, but the inversion is direct to cristobalite, and there is a shift in the inversion point to as low as 1000 deg. C. (1832 deg. Fahr.) while at 1300 deg. C. (2372 deg. Fahr.) the change is very rapid.

This entire absence of tridymite in quartz heated well above 870 deg. C. (1598 deg. Fahr.) the quartz-tridymite inversion point, although difficult of explanation, is apparently proved. As indicative of the time element requisite for such an inversion, in one experiment fine-ground quartz heated 108 hr. at 1250 deg. C. (2282 deg. Fahr.) without flux gave but a small percentage of inversion while with 90 hr. at 1360 deg. C. (2570 deg. Fahr.) approximately two-thirds became cristobalite.

In considering these changes in the crystalline form of silica, some of the characteristic properties of the three will not only make clearer the method of distinguishing them, but also throw some light on the reasons for the effects these inversions exhibit.

Quartz has a specific gravity of 2.65, tridymite of 2.27, and cristobalite of 2.33. Each has its characteristic crystal form, the quartz being usually in the familiar pyramids, prisms or combinations of these. Tridymite often occurs in thin tablets or plates hexagonal in shape. Cristobalite is exceedingly irregular in the development of its crystal form but often develops octahedral caps along the closely interlacing axes of elongation.

It is the difference between the indices of refraction of these minerals, however, that furnishes the greatest aid in distinguishing the one from the other.

Tests.—As a starting point from which to work in determining the effect of burning, a set of sample silica brick were taken from one kiln, all from the same zone

and from a kiln of absolutely normal burn. In this instance they were first burned at a point about 8 ft. from the wall and 6 ft. from the bottom. This sample was divided into three parts, one to be kept unaltered, one to be reburned under the same conditions, and a third to have two reburns. In addition to this, pieces of quartz rock received one and two burns respectively, with the view of obtaining the same data.

The primary object was to determine, if possible, how far the inversion from quartz to cristobalite had progressed under the successive conditions. Each burn was made as nearly uniform as practicable, and in each succeeding burn the effort was made to maintain identical conditions. At that part of the kiln where these brick were burned the temperature reached 1540 deg. C. (2804 deg. Fahr.), and they were subjected to that heat for approximately 40 hr.*

In general, the chief optical constant serving to distinguish cristobalite on the one hand from quartzite and calcium silicate on the other was the index of refraction. The slow ray of quartz has a refractive index of 1.544 while the index of the fast ray of cristobalite is about 1.485. The immersion method was used to determine the indices of the grains, the powdered brick being immersed in a liquid of index 1.51. By this method it was possible to distinguish between the higher-refracting quartz and calcium silicate and the lower-refracting cristobalite.

With the aid of a *camera lucida*, the fields were sketched on very thin tracing paper. The grains, as represented on the paper, were then cut out and weighed for each constitutent. Aside from the fact that the composition of different fields may vary, other errors are entailed in the sketching, cutting out and weighing so that a variation of 5 per cent is justifiable. In these determinations the fields of the same specimen checked to within 5 per cent maximum and 1 per cent minimum error.

Results.—The tabulated data are as follows:

Specimen	Field	Quartz and Calcium Silicate, Per Cent	Average, Per Cent	Cristobalite, Per Cent	Average, Per Cent
Lot 1	1	24.87	.....	75.13	.....
(1st burn)....	2	20.42	22.65	79.58	77.35
Lot 2	1	14.31	.....	85.69	.....
(2d burn)	2	19.96	17.13	80.04	82.87
Lot 3	1	17.44	.....	82.56	.....
(3d burn)	2	14.60	16.02	85.40	83.98
Quartz rock	1	50.08	.....	49.92	.....
(1st burn)	2	51.05	50.57	48.95	48.95
Quartz rock	1	32.70	.....	67.30	.....
(2d burn) 2		30.06	31.38	69.94	68.62

A number of interesting deductions may be made even from these preliminary tests. The maximum change takes place at the first burning, followed by a further appreciable inversion at the second, and practically no change at the third.

The grain structure of the reburned silica brick may throw some light on this subject. Here the grains may be seen to be essentially cristobalite, with the quartz occurring as an inclusion. The last stages of the inversion are apparently exceedingly slow within the protecting envelope.

The smaller percentage of inversion in the case of the quartz rock as compared with the brick is very noticeable, and is undoubtedly due to the grinding of the quartz in the manufacture of the brick. This is wholly in line with Fenner's laboratory experiments, in which he found the influence of comparative grinds to be slight if the silica mineral were heated with a flux, but to be marked if the material were heated without a flux. Fine grinding greatly hastened the inversion. The greater freedom of movement in expansion as compared with the exceedingly dense quartz body is probably the controlling factor, rather than any difference in the penetration of the heat.

The part played in the inversion (if any part is played) by the lime and its compounds present, is of much interest. It appears logical that the greater fluidity conferred by the fluxes present should have an influence; but it must be borne in mind that, as compared with previous experimental work on silica minerals, the amount of flux present in the brick is exceedingly small, and that definite chemical compounds are formed in combination with the brick body. In Fenner's work the sodic tungstate formed no such chemical compounds, and remained unchanged at the conclusion.

The fact moreover that no tridymite was determinable in either the burned brick or the calcined quartz indicates that the burning of silica brick is closely comparable to heating the quartz without a true flux or catalyzer; for did the impurities of the rock and the added lime act in that manner, tridymite would undoubtedly be distinguishable.

Thus far, we have assumed the changes in crystal form to be desirable, because of their effect on the expansion of the material.

EFFECT OF BURNING ON PHYSICAL STRENGTH

It is also of interest to note the effect of the reburning on the physical strength of the brick. To determine this, the following tests were run:

CROSS-BREAKING OR MODULUS OF RUPTURE TEST

Number of Burns	Mark	Breadth of Brick, Inches	Depth of Brick, Inches	Weight Causing Fracture of Brick, Pounds	Length Between Supports, Inches	Rupture, Pounds	Average, Pounds
1	9 A	2.46	4.40	3,550	6	671	.....
1	9 A	2.42	4.40	3,000	6	567	624
2	9 B	2.50	4.50	4,140	6	730	.....
2	9 B	2.50	4.50	5,000	6	889	809
3	9 C	2.06	4.50	4,500	6	971	.....
3	9 C	1.96	4.50	4,550	6	1,031	1,001

CRUSHING TEST; WHOLE BRICK CRUSHED FLAT

Number of Burns	Mark	Dimensions, Inches	Area, Square Inches	Load, Inches	Crushing Strength Per Sq. Inch, Pounds	Average, Pounds
1	9 A 2	9.00 by 4.40 by 1.96	39.60	176,800	4,465	.....
1	9 A 2	9.04 by 4.44 by 2.04	40.14	167,000	4,161	4,313
2	9 B 2	9.10 by 4.46 by 2.02	40.58	186,500	4,596	.....
2	9 B 2	9.10 by 4.40 by 2.06	40.04	168,000	4,196	4,396
3	9 C 2	9.06 by 4.42 by 2.00	40.04	195,000	4,870	.....
3	9 C 2	9.12 by 4.46 by 2.06	40.68	168,000	4,130	4,500

The increased strength of the brick is evident.

Conclusions

In considering whether or not all the expansion possible is burned out of the brick, it is necessary to determine first the limits and then how closely they are approached.

Day, Sosman and Hostetter say that the true specific volume of cristobalite as compared with quartz at 20 deg. C. is 13.4 per cent greater. Assuming a green brick to be wholly pure quartz (100 per cent SiO_2), and the brick burned from it wholly cristobalite, the volume increase would then be 13.4 per cent. This theoretically possible expansion is diminished by the effect of the impurities present in the actual brick, and by the resulting compounds formed. For instance, 4 per cent of impurities would produce a much larger proportion of compounds to which this expansion formula does not apply.

An expansion of, say 3/8 to 7/16 in. per foot, to which byproduct coke-oven silica is burned, thus provides for somewhat more than 13 per cent increase in volume.

It must be borne in mind, however, that by quick burning the brick may be easily expanded by double or

*The heartiest appreciation is here expressed to A. A. Klein, Petrographer in the U. S. Bureau of Standards at Pittsburgh, for his courtesy in making these determinations that they might be concluded in time for presentation here. The quality of Mr. Klein's work needs no comment.

treble the normal amount; but sound brick do not result. This excessive expansion is due to minute fissures opened up in the body of the brick by a too sudden rise in temperature during burning. In the early stages of firing the heat must be raised very slowly. In general the conclusion is justified that the present good commercial practice carries the results of the quartz-cristobalite inversion to the greatest degree economically possible and that the measure of the expansion of the brick affords a closely approximate measure of the inversion—providing only that the brick are sound.

The short series of tests outlined above are given with full realization that, while indicative, they are by no means conclusive. They were but the preliminary runs, necessarily made somewhat in haste, but giving data which permit intelligent plans to be made for the more comprehensive tests now under way. There is much to be learned as to the effect of both time and temperature as well as the influence of pressure, which may produce a shifting of some of the inversion points. Judging from the work thus far done, it is impossible to expect the full inversion of quartz to cristobalite under any practical operating conditions of manufacture.

Harbison-Walker Refractories Co.,
Pittsburgh, Pa.

Unstable States in Arc and Glow*

BY W. G. CADY

In solid and liquid conductors, in which Ohm's law is applicable, unstable states, where a small variation in voltage produces a large change in current, are almost unknown. Exceptions occur only when a critical state in the conductor is reached, as, for example, in an iron wire at a certain temperature, or in an aluminium valve cell at break-down voltage.

Characteristics of the gas discharge.—When an electric current passes through a gas, the number of available carriers of the discharge increases with increasing current at a very rapid rate. In a popular sense, an ionized gas is a most "unstable" conductor, having a resistance by no means amenable to Ohm's law. In the language of dynamics, however, a gas discharge is normally stable in the sense that there is a restoring force to damp out small disturbances. The nature of this force, as well as the criterion for stability of any discharge, can be understood best by reference to the characteristic curve of the discharge, Fig. 1.

This curve shows qualitatively the relation between current and voltage in the discharge between two fixed electrodes. The nature and pressure of the surrounding gas are supposed constant, except as modified by conditions at the electrodes themselves. All of the common types of discharge are represented on this diagram. With a sufficiently high emf. it is theoretically possible, by decreasing the external resistance, to pass through all the stages in succession. Practically certain portions are unattainable, and different sources of supply are necessary for different forms of discharge. In any case, however, the curve is characteristic of the discharge apparatus and not of the supply.

The first part of the curve, *OA*, represents the saturation current, which soon assumes a value that is practically constant over a great range of voltage. This current is carried by the few free ions that are always present. As the voltage increases, the charged particles are sufficiently accelerated to form new ions by impact. At this point the current begins to increase, and a faint glow appears. The point *A* represents the sparking potential. In the present case the external resistance is supposed to be too high to admit of sparking.

AB is the glow discharge proper, in which the rate of ionization is so great that the voltage across the gap begins to drop. If the cathode is small, the curve may rise again before *B* is reached, owing to the abnormally high cathode drop.

Since the drop at the cathode is much larger than that at the anode, the cathode becomes relatively hot. As *B* is approached, the expenditure of energy at the cathode becomes so high that the cathode rapidly becomes incandescent. Here a new phenomenon appears, namely, the emission of electrons from the hot cathode, according to Richardson's law. These greatly increase the

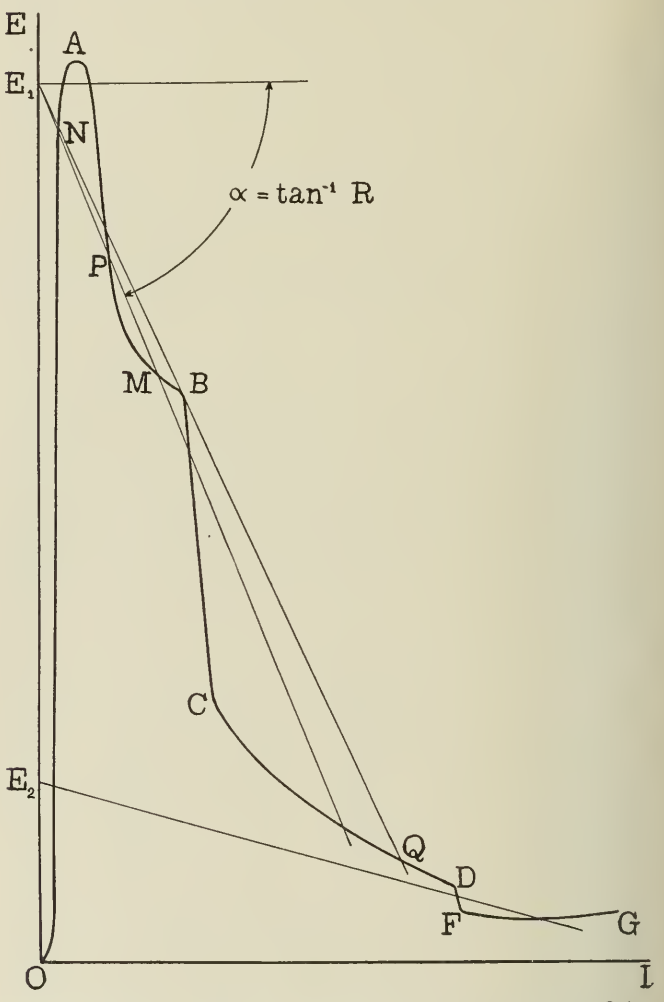


FIG. 1—CHARACTERISTIC CURVES OF GAS DISCHARGE. *OA*, SATURATION CURRENT; *AB*, GLOW; *CD*, ARC, FIRST STAGE; *FG*, ARC, SECOND STAGE

ionization close to the cathode, and the positive ions thus produced heat the cathode by impact still more. If the cathode metal is volatile enough, it begins to vaporize, thus lowering the cathode drop as well as the resistance of the gas.

The discharge quickly resolves itself into an arc, in which the negative base is concentrated to an intensely bright spot, the current is carried chiefly by the vapor from the cathode, but in which the mechanism of the discharge is essentially as before. The portion *BC* of the curve cannot be observed. Over *CD* the discharge is an arc as far as the cathode is concerned, but since less energy is being expended at the anode, at the latter we may still have a glow discharge. The positive base of the discharge is still diffuse and faintly luminous. This is the *first stage* of the arc.

*A paper read before the New York Section of the American Electrochemical Society on November 11 in joint session with the Illuminating Engineering Society.

With increasing current the anode is brought to the boiling point. This causes a decrease in the anode drop and a further increase in conductivity of the gas, so that the portion *DF* is quickly passed over. *FG* is then a full arc, or *second stage* arc. Exceptions to this typical sequence of events will be described below.

Quantitatively it is impossible to make the diagram give a correct idea of the voltage and current relations, since the current at *G* is in reality many thousands of times greater than at *A*.

Stability of the discharge.—While theoretically it is possible to maintain a steady discharge at any point of the entire curve, practically the transition from one portion to the next is always discontinuous. As the voltage or the external resistance is varied, a critical point is always reached where the discharge is absolutely unstable, changing abruptly to a stable region on another part of the curve. Still, with any given supply emf. and external resistance, it is always possible to predict between which two points the discharge must change. The method of procedure is largely due to Kaufmann.[1]

Let us suppose that the supply emf. is measured by OE_1 in the figure. If *M* is the point on the curve at which the discharge takes place, then since the ordinate of *M* is the voltage consumed by the discharge, it is evident that the external resistance *R* is equal to tan α. If *R* is decreased, α must decrease and *M* will move to the right along the curve.

Kaufmann showed analytically that a stable discharge is only possible when the line through E_1, or the "resistance line" as it is called, *slopes more steeply than the charactertistic curve* at the point in question. Thus the discharge is stable at *M*, and, starting with zero current, it would also be stable at *N* with the same external resistance, but not at *P*. A glow at *P* could only be obtained with an enormously high emf. At *B* the discharge is unstable; this is the first of the unstable states to which attention is directed. As soon as the point of tangency is reached, the discharge changes abruptly to a first-stage arc at *Q*. If now the external resistance is increased, the discharge does not change back to a glow along *QB*, but owing to the vaporization of the cathode it remains an arc until the point of tangency at C is reached. Then if, as is usually the case, the discharge cannot change to a stable glow, it goes out.

Similar points of instability exist at *D* and *F*. If the supply emf. is low, as at E_2, not even the first stage of the arc is possible, but only the second. This is the case with most arcs, operating with low emf. and small external resistance, and lighted by touching the electrodes together.

The physical significance of Kaufmann's criterion may be seen from the following considerations: If the resistance line slopes more steeply than the characteristic curve, then if through any chance the discharge at a given instant happens to take place at an abnormally high current, it cannot persist at this current, since the voltage available for the discharge is limited by the external resistance, and the steep slope of the resistance line brings the operating point too low for the discharge to be maintained; hence the current settles back to its normal value. Similar reasoning will show that if the resistance line slopes less steeply than the characteristic curve, then any slight disturbance will grow until the discharge goes out or becomes stable at another part of the curve.

In a general way this sort of stability is, of course, analogous to the mechanical stability of a pyramid, which is stable or unstable according to whether it stands on its base or is balanced on its point. A more exact analogy would be furnished by a hydraulic model, in which the discharge tube was represented by a valve so contrived as to open wider the greater the flow of water through it. This would provide the "falling characteristic." If then the water were supplied from a vessel of variable height, and regulated by a valve at the supply, it is evident that at high pressure and with supply valve nearly closed any given flow of water would be maintained more stably than if the pressure were low and the supply valve wide open, for in the latter case a much greater percentage of the total "resistance" would be in the valve of "falling characteristic."

Kaufmann applied his criterion of stability with great success not only to glow and arc, but to the point discharge, to a discharge gap ionized by an external source and, most remarkable of all, to the case of a discharge having a capacity in parallel with it. This came pretty near being the discovery of the singing arc, which, by a coincidence, was discovered experimentally by Duddell in the same year.

The carbon arc.—I have obtained a glow discharge and both stages of the arc between carbon terminals, using an emf. of 460 volts, in nitrogen at reduced pressure. Air was then admitted and the current increased until the hissing state was also reached, making four forms of discharge with the same electrodes. On the characteristic curve for carbon electrodes the hissing point would be represented by a kink similar to that at *DF* in Fig. 1, but situated between *F* and *G*. The laws governing the current-voltage relations on transition between normal and hissing carbon arcs are the same as those discussed above.

First and second stages of arc. Effect of impurities.—The unstable state occurring between the first and second stages of the arc has been investigated by Arnold and the writer. It is on the first stage that the ordinary mercury arc burns, having an anode of iron or graphite. The change from first to second stage has now been observed with anodes of a large number of metals, though in some cases reduced gas pressure or exclusion of oxygen was necessary.

An instability in the discharge is sometimes occasioned by traces of impurities on the surfaces of the electrodes. It is well known that the glow tends to change to an arc more readily if the metallic cathode is contaminated with traces of oxide. This is related, of course, to the emission of electrons from hot oxides. At the anode in a glow or a first stage arc, traces of impurities serve as nuclei around which the discharge tends to become concentrated, though it is still a glow. This effect may become so pronounced as to be taken for a new type of dischage,[2] especially since the voltage suffers a sudden drop when the concentration sets in.

An unusual type of arc.—A very unusual type of discharge is that in which, as the current increases, an arc appears at the anode while there is still a glow at the cathode. Those who define the arc as essentially a cathode phenomenon will not be disposed to admit that this is an arc at all, yet it has every characteristic of an arc at the anode, and the appearance here does not alter further when the arc phase sets in at the cathode. The writer has encountered this form of discharge with anodes of C, Ag, Cu and Hg, the cathode in most cases being of silver. The condition is decidedly unstable.

Is an arc possible from a pure metal?—The writer observed some years ago that a cathode of pure silver may become heated by the glow discharge in nitrogen nearly to the boiling point without the formation of an arc. At currents as high as 1.3 amp. the

[1] Kaufmann, Annalen d. Phys. 2. p. 158, 1900.

[2] Hagenbach, Phys. Zeitschr. 12, p. 1015, 1911.

discharge is still a glow, though the molten metal is white hot and vaporizes so intensely that clouds of silver "steam" fill the discharge tube. This is important evidence that incandescence and vaporization of the cathode are not enough of themselves to cause the formation of an arc. Whether even at the boiling point of silver the glow would still persist if no impurities were present cannot be stated. In the present tests, at the highest currents the cathode mantle always grew so large as to encroach upon the fringe of impurities that inevitably surrounded the molten mass, and then an arc immediately formed. The admission of a small quantity of oxygen also precipitated an arc.

Intermittent discharge. Corona.—Both glow and metallic arc, as well as the discharge from points, are sometimes found to be intermittent. For this to be the case, the current must be relatively small and the capacity of the external circuit considerable. There is usually a certain critical external resistance at which the intermittence vanishes, as shown by the cessation of sound in a telephone connected to the circuit. The phenomenon is closely related to the use of the arc as a generator of electric oscillations. The Cooper-Hewitt mercury interrupter is a notable example of intermittent arc.

In a strong magnetic field an arc can also be made intermittent. In this case the instability is due to the lengthening of the column of vapor by the magnet, causing the voltage to rise above the point where the discharge can be maintained. Owing to the incandescence of the cathode, the discharge quickly relights and the operation repeats itself.

The corona discharge from high voltage transmission lines is similar to a glow discharge, and is said to be often intermittent. It exhibits the characteristic cathode and anode phenomena, as well as the tendency to concentrate at certain points which was mentioned above. Since the air serves as one electrode, the corona has in some respects more in common with the discharge from points than with the typical glow.

Rotations at the anode.—Two effects will now be described, illustrating the instability of gas discharges as certain currents. The first of these has to do with the anode, the second with the cathode.

In the iron arc in free air the discharge normally takes place between globules of molten oxide. The second stage sets in at a little over an ampere. A close examination shows that the bright spot at the positive end of the arc is in rapid rotation, describing a minute ring. As the current increases this form of rotation suddenly changes to one in which the ring is still smaller, then at about 1.8 amp. a large ring takes its place, which presently yields the stage to a smaller ring again.

Each of the four types of rotation has its characteristic diameter and speed, and produces a faint note of a certain pitch. Oscillograph records show that the current and voltage undergo corresponding changes. Reasons have been given elsewhere[3] for believing that these movements are due to a reduction of the oxide at the positive base of the discharge, causing the base to wander to regions richer in oxygen. The changes from one type to the next are probably due to modifications in the composition of the oxide, brought about by increasing temperature. I have found similar effects to a slight extent in nickel and cobalt. These results have a bearing on the use of the iron arc as a wave-length standard in spectroscopy.

Glow-arc oscillations.—The effect at the cathode to which reference has been made is of the nature of a rapid pulsation back and forth between glow and arc. To obtain it, the supply emf. must be high, and the gas should be hydrogen at atmospheric pressure, mixed with a little hydrocarbon vapor. The electrodes may be of any metal, placed very close together, the discharge current being of the order of 1/10 amp.

When the discharge is a glow, a spot on the cathode becomes heated to such a degree that a small arc forms, but the voltage then drops so much and the current increases so little, owing to the shape of the characteristic curve, that the energy is too slight to maintain the arc, and immediately the glow sets in again. Such pulsations between arc and glow are of a frequency anywhere between 1 and 250,000, depending on various conditions. I have succeeded in converting 66 per cent of the power applied to the discharge into high frequency oscillations of this type. Unfortunately, the nature of the discharge is such that the conversion of large amounts of power by this means is impossible.

In these experiments no capacity was connected in parallel to the discharge, though the adjacent parts of the circuit acted as capacities for the high frequency currents.

The singing arc.—In the singing arc, including the Poulsen arc used in radio-telegraphy, a capacity and self-inductance in series are placed in parallel with the arc. The effect of the capacity is to drain energy from the arc when the current in the condenser circuit is in one direction, and to strengthen the arc current when in the other direction. Continuous oscillations are thus maintained, the condenser circuit receiving energy and timing its own impulses in a manner analogous to the balance wheel or pendulum of a clock.

The point of chief interest here is that, as Kaufmann, Simon and other have shown, such oscillations are possible only when the arc (or glow) possesses a falling characteristic. Simon has found that the alternating-current, or "dynamic," characteristic differs from the direct-current, or "static," characteristic, the difference being due to a sort of hysteresis, and that the result of this is that at high frequency the dynamic characteristic tends to change from a falling to a rising type. This limits the attainable frequency, but by reducing the hysteresis and choosing such conditions as will make the characteristic fall as steeply as possible, frequencies of over a million are easily reached.

If the oscillations are weak, the direct current through the arc simply fluctuates. This can occur with the carbon arc. If the oscillations are stronger, they put the arc out at each cycle, and before the arc relights the condenser becomes charged. The oscillating arc used in radio-telegraphy is of this type. A third type, in which the oscillations are powerful enough to make the arc relight in the opposite direction, produce a coarse tone and are not much used.

Effect of second harmonic.—When the oscillations are of the second type, extinguishing the arc at each cycle, the wave form is very complex. The second harmonic is especially prominent. As an example of oscillations of this type of audible frequency, the following experiment may be described.

A carbon arc is made to sing by connecting a large capacity and a self-inductance coil of low resistance in parallel with it. A second coil is connected to a capacity such that the natural period of the secondary circuit is nearly the same as that of the circuit connected to the arc. When the two coils are brought near together, the pitch of the arc changes, owing to the effect of close coupling. If the pitch falls, it can be made to reach an unstable value from which it suddenly jumps up a whole octave, the discharge remaining stable at this higher pitch.

The explanation of this is, that when any two oscillating circuits are closely coupled there are two possible frequencies, one higher and one lower, in either of which

[3] Phys. Rev. 2, p. 249, 1913.

oscillations may take place. At a certain stage of coupling the higher frequency is just an octave above the lower. If now the arc is on the lower frequency and has a very strong second harmonic, then if resonance is also possible at the octave above, the harmonic may be reinforced to such an extent as to assume the rôle of fundamental frequency itself. The pitch then rises to the higher octave.

It is hoped that the phenomena that have been described may serve to illustrate the unstable nature of some forms of gas discharge, as well as the very diverse ways in which the instability asserts itself.

With respect to practical conclusions, the following may be said: for stability, an arc should be operated with supply emf., external resistance, and current all large. Or if the discharge is to be a glow, a region on the characteristic should be chosen at a safe distance from a critical point, having due regard to the supply emf. For oscillations, a steeply falling characteristic, small current, large emf. and artificial cooling of the electrodes are important factors.

Wesleyan University,
Middletown, Conn.

Notes on Chemistry and Metallurgy in Great Britain

(From our London Correspondent)

The General Situation in Great Britain

When a patient is in the throes of fever, when all normal functions are interrupted, and when several organs overstrained perform new functions, comparative standards by which to mark progress are not easily chosen. The world has had biggish wars before this, but none so big or so complex in economic and industrial aspects. Reckoned against all previous prophesies it was never considered possible that European civilization could have fought for so long or maintained such huge armies without utter collapse. Yet the collapse is far off when one or other group will throw up the sponge.

You, on your side should be seeing most of the game, but as you only see it through the filtering medium of censorships it is possible that the little we do see here of our own condition is of more utility to us as a combatant than the wider survey of a neutral.

Despite casualty lists, despite increasing indebtedness, despite the increasing conversions of factories and foundries to make munitions for our armies, the general outlook is one of confidence. Of course, there is the masked anxiety of those whose relatives are in the trenches, but it is well masked.

Blunders, of course, there are, but administratively we are much more likely to suffer because those in authority are honest fools than because they are clever rogues. With free ports and open seas raw materials and foodstuffs cause us no anxiety. The harvest season being almost over, recruits from the industrial class which can best spare them, will come forward. Despite the ill-advised advertisement given by the press to certain cranks the labor situation has greatly improved.

But in one respect there is cause for alarm, an alarm as to the consequences of the present high wages, good employment, and resultant present extravagance. To a certain extent the latest budget will check the tendency to extravagance, and for the rest, stern necessity will in due course intervene, and forcibly deal with the fruits of an unhealthy and abnormal activity.

The British Association Meeting

Among the many papers and sectional presidential addresses that by Dr. H. S. HELE-SHAW to the Engineering Section stands out with much prominence. Dr. Hele-Shaw is among those, who, while giving full attention to present needs is also giving careful consideration to the problems which will follow the end of the war. He says, "I do not believe the Germans despise us for our want *per se* of the application of science to industry. I do not think they have much reason to; but what they do despise us for is the want of co-ordination, which, I venture to say, amounts to positive slackness, which they are keen enough to observe permeating the whole of this country. They see different sections, instead of being united for a common end, quarreling with each other, filled with mutual suspicion and distrust, with apparently no common bond of union, and whereas the German is proud of the Fatherland, he sees in this country large numbers who seem, either through self-consciousness or ignorance, to be ashamed to mention the subject of the British Empire, or, what is worse, to acknowledge that any love of their country is or could be a mainspring and incentive to strenuous effort. . . .

"When peace is concluded, it will only be a prelude to another war, and a war which will recommence with a far greater energy on the part of our enemy than before, viz., the war of commerce—and the latter will be almost as serious for us as the more sanguinary one. This will be so even if we are victors, for 'after a long war the difficulties of the victors are often greater than those of the conquered. The conquered have their attention directed to the reparation of losses and are inspired by a patriotic desire to submit to losses for the sake of their country. The victors are in the frame of mind which expects everything to be easy.'

"Remembering how swiftly we relapsed into national ease at the end of the Boer War, it behooves every man who can do so to take his share in making ready for the terrific struggle Germany is certain to put up in the arts and manufactures. We shall better appreciate what this competition will mean if we consider the marvelous stride made by Germany during the last half-century in the arts and manufactures. It is undoubtedly in the matter of scientific organization even more than the organization of science that Germany has achieved such wonderful results, and it is, therefore, in this direction that we must leave no stone unturned if we wish to have any chance of holding our own in the future."

Also of importance was Prof. W. R. SCOTT'S presidential address to the Economic Science Section—speaking of the probable situation at the end of the war, Professor Scott pointed out that there may be a short trade boom (arising out of an attempt to restore some of the material ravages of war), but the joint demand from it and from the trades reopened is likely to be considerably less than the huge present expenditure of manufacturers for war. Thus the unemployment occasioned by dislocation of industry through hostilities is likely to be carried forward as a species of suspense account which must be liquidated not very long after peace. Moreover, international credit is likely to re-act on the situation in a prejudicial manner. Even already the financial system of Germany is more strained than appears on the surface. The fact is advantageous to us as belligerents, but it will probably be prejudicial to us not long after the re-establishment of peace. At present much of the inconvertible paper circulating on the continent does not affect us here. When the inflation has to be squeezed out after the war, a disturbance of credit is not unlikely.

"A special aspect of the problems under discussion is the provision of capital for re-starting of trades contracted by the war, and for the restoration of Belgium and other regions desolated during the progress of hos-

tilities. Chalmers, writing a hundred years ago, supposed that in cases of this kind 'in a very few years the recovery both of population and labor would be completed.'

"The explanation which he gave was far from satisfactory even for the time at which it was written, and it is still more deficient as applied to the present circumstances, when in industrial countries, fixed capital is much more important than in Chalmers' day. In the last quarter of a century, any great catastrophe, such, for instance, as the partial destruction of San Francisco by earthquake and fire, has been repaired with comparative ease by bringing capital from outside. But the waste of war renders capital exceedingly scarce; in fact, a famine of capital after the war has been predicted. Such an anticipation is over-pessimistic, but capital is likely to be obtainable for a time only with some difficulty. It is to be feared that after the war Europe will experience very considerable straits for several years to come. Not only must the waste of war be made good, but its evil legacy in inflated funded and floating debts must be gradually dealt with, lessening by reason of increased taxation the normal margin for new savings. Increased work and greater economy are the only remedies, aided by improved methods of production.

"It is to be hoped that some of the inevitable loss will be repaired in time by better methods of organization and by an accelerated rate of invention. The waging of a just war results in quickening of the national spirit. It forces a nation out of the easy and well worn paths of custom and convention. Thus out of all the suffering and all the loss, some good will come. The large proportion of our young manhood, which has gone to serve the country on the seas or in the field, and which returns having looked death in the face without being afraid, will not take up life where it was left. The noble qualities that have been evoked by the stress of battle will remain and will influence civil life during the next generation. The outlook will be both broader and also more simple."

Your correspondent has quoted somewhat extensively but not wholly prematurely from two important pronouncements. It must, of course, be recognized that the end is not yet, much water must first flow under London Bridge, many corpses choke the ditches in Flanders, and much blood trickle down to the waves of the Aegean before we can ever think the end is in sight. But just as the longest and weariest route march is cheered by the thought of rest and refreshment at *billets,* so in the months or years of a war, seemingly long drawn, it will do no harm to consider what fresh arrangements will be made when the time for that change of occupation which amounts to rest comes, so long as that consideration is of the serious order and takes full account of new difficulties to be faced.

The National Physical Laboratory

PROGRAM OF RESEARCH WORK FOR 1915-16

The following statement of work proposed for the current year in the Department of Metallurgy and Metallurgical Chemistry has been adopted by the General Board.

1. METALLURGY

Alloys Research.—The work outlined in the report for 1913-14 will be continued. The forging and rolling of a considerable number of light alloys will constitute a large part of the work for the year. The theoretical study of the aluminium-zinc-copper system, and the investigation into the permanence of light alloys will also be continued.

The work on the Effects of Stress on Steel at High Temperatures, on the Intercrystalline Cohesion of Metals, and on the Melting Point of Iron in Vacuo, will be continued with the new apparatus which has been obtained and set up for that purpose.

Acetylene Welding.—An investigation of acetylene welds will be carried out in conjunction with the Engineering Department.

Magnet Steels.—The research on magnet steels will be continued in co-operation with the Physics Department.

Volume Changes in Metals and Alloys on Fusing.—This research, which has been delayed owing to serious experimental obstacles, will be resumed, when circumstances permit, by means of new methods which have recently been devised.

Systematic Study of Steels.—The developments in the apparatus for taking thermal curves and for carrying out quenching and annealing which have taken place during the past few years, now render it eminently desirable that these new and more accurate methods should be utilized for a re-investigation of the thermal curves and micro-structures both of the fundamental carbon steels and of the more important special alloy steels derived from them. The latter study is particularly important in view of the increasing rôle which these special steels play in the investigatory test work of the department, particularly in connection with aeronautics. The systematic study indicated is, however, a large matter, involving a very considerable amount of work, and it is, moreover, correlated with the progress of two other researches, viz.: that on the melting point of iron in vacuo, and that on the effects of stress on steel at high temperatures. The present staff, and to some extent the equipment, of the department, do not permit of such an extensive investigation being taken up vigorously or with any hope of early completion. It is, however, so important that it is hoped to make a beginning as soon as circumstances permit.

II. METALLURGICAL CHEMISTRY

The study of analytical methods, and the further improvement of the methods in use in the Department, will be continued. Questions arising out of these matters will be investigated.

Investigations in conjunction with various industrial developments and problems arising out of war conditions will be undertaken.

With regard to electrotechnics and photometry, in regard to the latter the development of suitable substandards for use in the testing of gas-filled electric lamps is becoming an urgent matter. Experimental standards have already been made up for the laboratory by the Osram Lamp Works, and are being thoroughly tested before duplication into complete sets of standards. The cascade method adopted at the laboratory for the realization of candle-power in white light will be eminently suited for extension to these sources of light of still higher efficiency. Four sets of gas-filled standards are required to bridge the color interval between the present high temperature standards operating at 1.5 watts per candle and those which are required in the testing of nitrogen-filled lamps, and their preparation and standardization will be pushed forward during the year.

The experiments on the coefficient of reflection of the white cards used in photometry will be continued and extended to some other materials, a knowledge of whose characteristics in this respect will be of practical value.

If opportunity permits, it is hoped to repeat to a greater accuracy and to extend the scope of the experiments on the method of color identity for the estimation of the temperature of glowing bodies.

Measurements are being made at the instigation of the British National Committee of Illumination to determine the correct flame height of the Hefner lamp to give one British candle.

In regard to electrotechnics, some investigations on micanite are in hand and nearing completion, while the main research work of the year will be a continuation of the research work on buried cables.

Market Prices

SEPTEMBER, 1915

Copper opened £67.17.6 and was 68.5.0 on the 2nd, it then fell to £66 on the 6th, but recovered and continued to increase to 70.7.6 on the 21st and after a drop to 69.12.6 (23rd) rose to £71 on the 28th and closes £72.

Tin opened £151.10 and went better to £154.10 on the 3rd, then steady at 152.10.0 till the 10th, when it improved slightly to £154.10 on the 13th; since slightly lower, recovering to £154 on the 21st, then dropping to £150 on the 23rd, and subsequently recovering to £153.5 on the 28th, and closes weaker, £152.

Iron, Haematite opened 95/— and remained at this price throughout the month.

Iron, Scotch opened 70/9, and, after a rise to 70/10½ on the 3rd became easier till the 9th when 70/10½ again was reached. It was lowered on 15th and 16th to 70/—, but recovered to 70/9 on the 17th, dropping then to 70/3 on the 21st, and 70/— on the 27th; settlement, 70/9.

Cleveland opened 64/9 and went to 64/10½ on the 3rd, then falling to 64/4½ (7th) and recovering to 64/10½ on the 10th. On the 13th it was again 64/9 and 65/— on the 13th. It subsequently went lower to 64/3 on the 21st and 64/— by the 24th; settlement, 64/9.

Lead opened £23.5.0 and reached £23.15.0 by the 3rd and £24 by the 10th. It remained at this till the 21st when appreciated to £24.5 and was £25 on the 24th and closes £25.5.0.

Aluminium, 98-99 per cent	£190	0	0
Antimony, black sulphide powder, cwt	3	15	0
Borax, British refined crystal, ton	23	0	0
Copper sulphate, ton	27	0	0
Caustic soda, 70 per cent, ton	10	0	0
Ebonite rod, lb	..	3	0
India rubber, Para fine, lb	..	2	4½
Mica, in original cases, medium	3. 6 to	6	0
Quicksilver (Spanish), bottle	16	7	6
Sal-Ammoniac, ton	53	0	0
Sulphur, recovered, ton	8	0	0
Shellac lb.	..	..	5
Platinum, oz., nominal	9	10	0

Recent Chemical and Metallurgical Patents

Gold and Silver

Continuous Agitation.—Apparatus for continuous agitation of ore slime, as in the cyanide process, is shown in Fig. 1, being the patented invention of CYRUS ROBINSON of Mount Vernon, N. Y. It consists of a

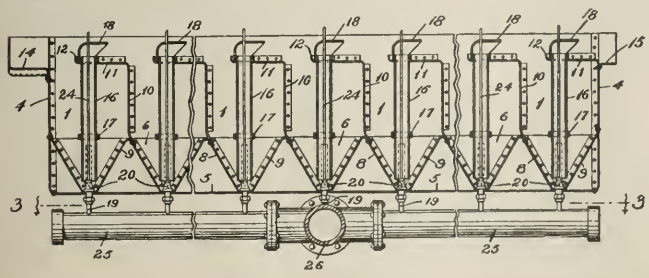


FIG. 1—AGITATOR

series of chambers connected, as shown. Extending beneath the chambers is a compressed air manifold with connections 19 to the bottom of each agitator. The latter has a central air-lift that is hooded in such a way that the discharged pulp is directed across an apron into the next agitator, and so on through the system, the pulp entering at 14 and issuing at 15. Regulation of the air used for agitation is accomplished by means of a nozzle 20 which has a beveled valve seat on which a conoidal valve closure rests. The closure has a depending finger that serves to protect it against lateral displacement and a vertical stem 24 which acts as a weight to hold the valve closed. (1,156,372, Oct. 12, 1915.)

Process of Cyaniding.—The diagram in Fig. 2 shows in considerable detail a patented procedure in cyaniding, by ROBERT S. TOWNE of New York City, and CYRUS ROBINSON of Mount Vernon, N. Y. The scheme

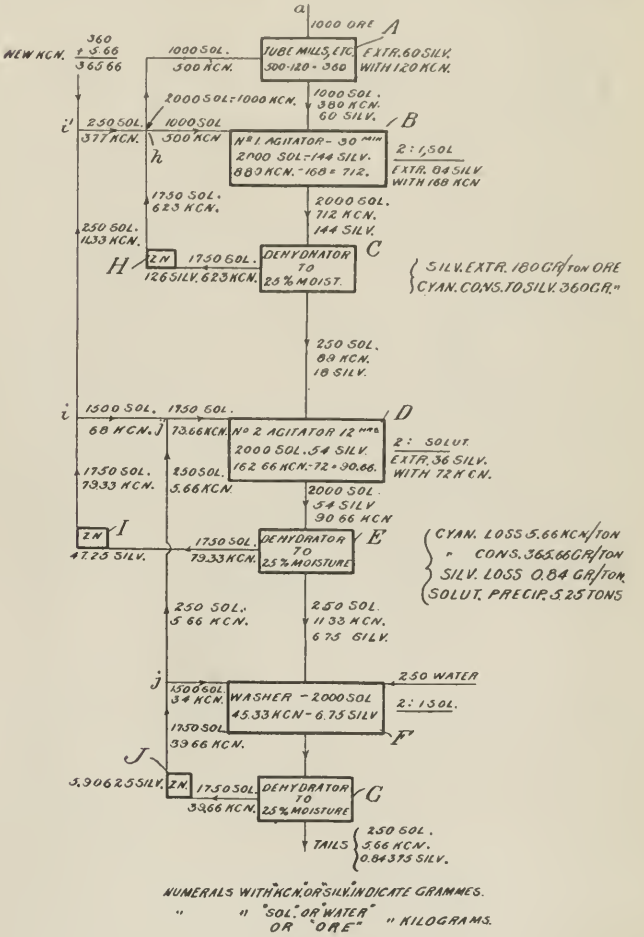


FIG. 2—PROCESS OF CYANIDING

is a multiple cycle process, the several cycles being successive in order and to a certain extent independent of each other. An object of the method is to effect extraction rapidly in a continuous process. It involves the use of a primary, relatively violent agitator and relatively strong solution, in combination with a secondary, relatively slow agitator and weak solution. The pulp is filtered between each step of the cycle so that the only solution flowing from one cycle to another is the amount carried with the dewatered ore. The quantity and strength of solution at various points can be regulated in accordance with the quantity and value of the ore, and the entire system maintained in equilibrium by the addition at an appropriate point of the proper quantity of fresh liquid and solvent. The diagram in Fig. 2 refers to the treatment of 1000 kilograms of ore containing 180 grams of silver per ton, for the extraction of which 360 grams of cyanide is required. (1,156,382, Oct. 12, 1915.)

Precipitating Metals from Solution.—A method of precipitating metals from solution, as, for example, gold and silver from cyanide solution by means of zinc dust, is patented by ROBERT S. TOWNE of New York

City, and Cyrus Robinson of Mount Vernon, N. Y. Previous methods of precipitating with zinc dust have made use of filter presses for the collection of the precipitant, but in this instance the inventors provide a settling or V-shaped receptacle, as shown in Fig. 3. The pregnant solution is mixed with zinc dust in any appropriate way and the mixture conducted through a pipe of considerable length before it reaches the separator, so that ample time for precipitation is allowed. The mixture is finally discharged from the pipe near the bottom of the receptacle 5, where the precipitate settles and is removed from the bottom. The solution freed from its precipitate flows upward and out of the tank by way of the launder 8. In order to prevent the upward flow and possible discharge of precipitate with the solution, a screen or grating 9 is placed across the tank, and on this screen is placed a layer of zinc in relatively finely divided form. This screen not only prevents the loss of precipitate, but also serves to obviate loss by re-dissolution of the precipitate while in the tank. (1,156,383, Oct. 12, 1915.)

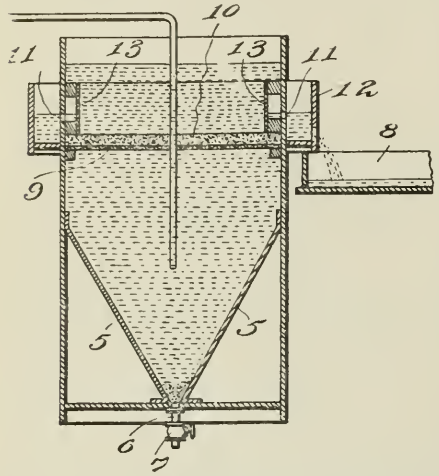


FIG. 3—DEVICE FOR PRECIPITATING AND SEPARATING METALS

Copper and Nickel

A process of separation of iron and nickel from copper in certain ores and metallurgical products is patented by Wilhelm Borchers and Eduard Thilges of Aachen, Germany. Experiments made by Lehmer at Aachen in 1906 showed that very pure metals could be produced by smelting sulphide ores with carbon and lime or limestone. According to this it would be easy to produce copper-nickel alloys by enriching a copper-nickel matte to a sufficient degree. But the market for copper-nickel alloy is not as good as for ferro-nickel, and since most copper-nickel ores and mattes contain iron sulphide in considerable quantity, it would be desirable to treat them for the production of ferro-nickel rather than copper-nickel. A high percentage of copper in the ferro-nickel, however, would be a disadvantage. The inventors have, therefore, discovered that copper can be separated from the greater part of the nickel and iron by melting copper-nickel matte with larger quantities of lime and smaller quantities of carbon than those used by Lehmer. In order to prevent the copper from separating in metallic form the matte is melted on a carbon-lined hearth of an electric furnace. Then an excess of lime is added, whereupon the iron and nickel sulphides are reduced and calcium sulphide is formed. The latter combines chiefly with the copper sulphide and prevents its decomposition. In this way it is possible by smelting comparatively poor copper-nickel mattes, to produce ferro-nickel, which is poor in copper and contains 15 to 20 per cent of nickel. (1,152,699, Sept. 7, 1915.)

Copper Hydrometallurgy.—The precipitation of copper from sulphate or chloride solutions by means of hydrogen sulphide and the reduction of cupric to cuprous sulphide with simultaneous generation of hydrogen sulphide for further use, form the basis of patents recently granted to Raymond F. Bacon of Pittsburgh, Pa. The preliminary treatment of the ore to put copper in solution can be carried out in any well-known manner. The resulting solution is treated with hydrogen sulphide, with the precipitation of cupric sulphide and regeneration of the solvent. To the precipitate is added elemental sulphur in quantity equal to one-half the sulphur in the sulphide, and the mixture

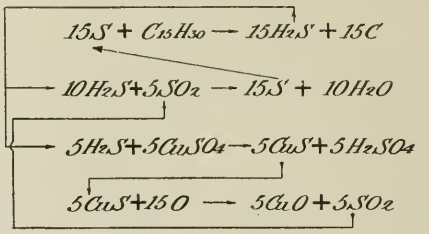


FIG. 4—COPPER HYDROMETALLURGY

is treated with a hydrocarbon body in a still at a temperature of about 300 to 360 deg. C., whereupon hydrogen sulphide is generated as a result of the reaction. Cuprous sulphide is formed and can be reduced by treatment in a converter or in any desired manner.

A related invention by the same patentee involves, first, the production of hydrogen sulphide by reaction between sulphur and a hydrocarbon; second, the use of a portion of the hydrogen sulphide to precipitate copper from a solution, and a portion to react with sulphur dioxide from roasting operations for the purpose of forming sulphur for utilization in the first step; third, roasting the cupric sulphide to oxide and treating the resulting sulphur dioxide as in the second step. The final products are carbon from the hydrocarbon treatment of sulphur and copper oxide from the roasting of cupric sulphide. These two products can be combined for the production of metallic copper. The relation of the different steps of the scheme are shown in Fig. 4. (1,151,234-5-6, Aug. 24, 1915.)

Electric Furnaces

Tapping Device for Electric Furnaces.—A simple method of tapping is patented by James G. Marshall of Niagara Falls (assigned to the Union Carbide Company). When the tapping spout is made of metal and exposed to the molten material it usually melts out.

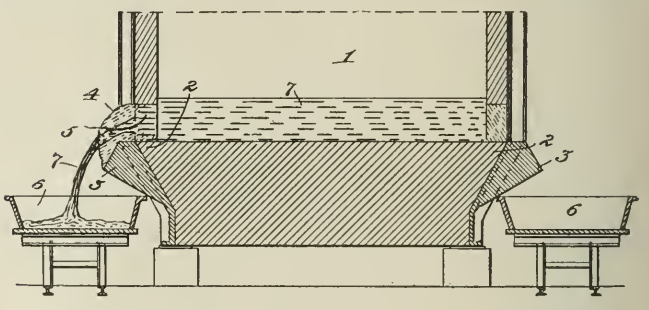


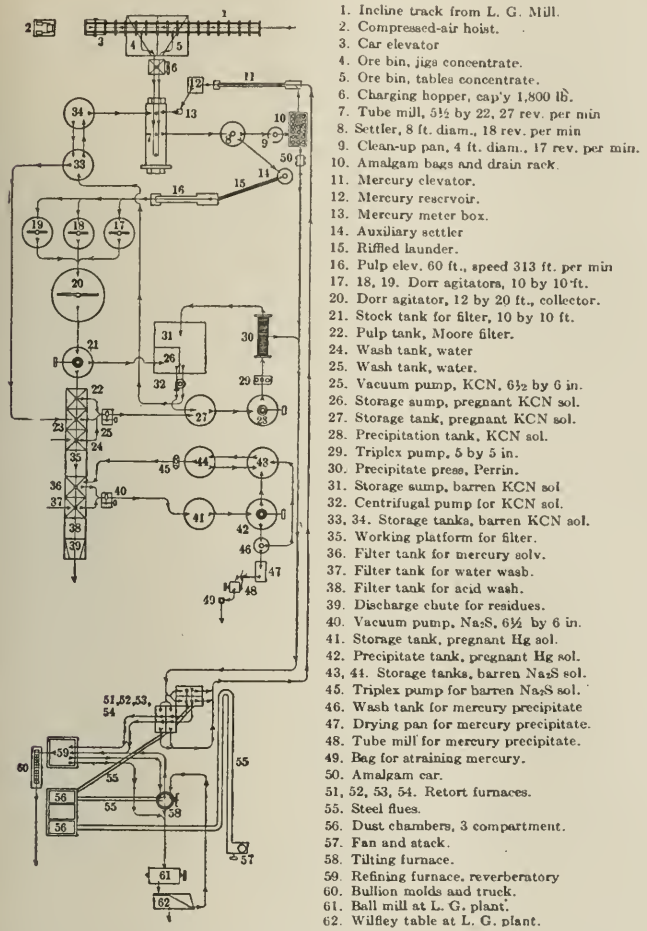
FIG. 5—TAPPING DEVICE FOR CARBIDE FURNACE

Repairs and renewals are inconvenient and costly. In the present method which is especially applicable to carbide manufacture, the furnace is made with an overhung hearth as shown at 2, Fig. 5. This allows the receptacle or chill 6, for the molten product to project under the furnace, and permits the tapping spout 3, to be merely a projection, so placed that it is not exposed to the direct heat of the molten material, but is protected by a layer of chilled material 4. In a carbide furnace the carbide chills rapidly on leaving the furnace, and an accumulation occurs at 4, thus preserving the spout. (1,149,203, Aug. 10, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Recovery of Mercury from Amalgamation Tailing, Buffalo Mines, Cobalt.—A paper by E. B. THORNHILL, metallurgical engineer for the Buffalo Mines at Cobalt, Canada, was presented at the San Francisco meeting of the American Institute of Mining Engineers, describing the process of recovering mercury from residues left



1. Incline track from L. G. Mill.
2. Compressed-air hoist.
3. Car elevator
4. Ore bin, jigs concentrate.
5. Ore bin, tables concentrate.
6. Charging hopper, cap'y 1,800 lb.
7. Tube mill, 5½ by 22, 27 rev. per min
8. Settler, 8 ft. diam., 18 rev. per min
9. Clean-up pan, 4 ft. diam., 17 rev. per min.
10. Amalgam bags and drain rack.
11. Mercury elevator.
12. Mercury reservoir.
13. Mercury meter box.
14. Auxiliary settler
15. Riffled launder.
16. Pulp elev. 60 ft., speed 313 ft. per min
17. 18, 19. Dorr agitators, 10 by 10 ft.
20. Dorr agitator, 12 by 20 ft., collector.
21. Stock tank for filter, 10 by 10 ft.
22. Pulp tank, Moore filter.
24. Wash tank, water
25. Wash tank, water.
25. Vacuum pump, KCN, 6½ by 6 in.
26. Storage sump, pregnant KCN sol.
27. Storage tank, pregnant KCN sol.
28. Precipitation tank, KCN sol.
29. Triplex pump, 5 by 5 in.
30. Precipitate press, Perrin.
31. Storage sump, barren KCN sol
32. Centrifugal pump for KCN sol.
33, 34. Storage tanks, barren KCN sol.
35. Working platform for filter.
36. Filter tank for mercury solv.
37. Filter tank for water wash.
38. Filter tank for acid wash.
39. Discharge chute for residues.
40. Vacuum pump, Na_2S, 6½ by 6 in.
41. Storage tank, pregnant Hg sol.
42. Precipitate tank, pregnant Hg sol.
43, 44. Storage tanks, barren Na_2S sol.
45. Triplex pump for barren Na_2S sol.
46. Wash tank for mercury precipitate
47. Drying pan for mercury precipitate.
48. Tube mill for mercury precipitate.
49. Bag for straining mercury.
50. Amalgam car.
51, 52, 53, 54. Retort furnaces.
55. Steel flues.
56. Dust chambers, 3 compartment.
57. Fan and stack.
58. Tilting furnace.
59. Refining furnace, reverberatory
60. Bullion molds and truck.
61. Ball mill at L. G. plant.
62. Wilfley table at L. G. plant.

FIG. 1—FLOW SHEET OF THE HIGH-GRADE AND MERCURY EXTRACTION PLANT

after amalgamating high-grade silver ore. A flow-sheet of the high-grade mill is shown in Fig. 1 and a chart of an amalgamation-barrel charge in Fig. 2.

In the amalgamation of high-grade ore in the Cobalt district considerable mercury is left in a residue, the metal being largely in the form of mercuric sulphide.

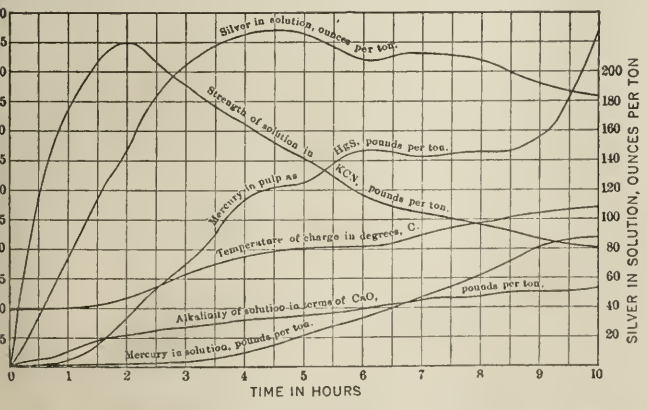

Silver in solution, ounces per ton.
Strength of solution in H2S, pounds per ton.
KCN, pounds per ton.
Mercury in pulp as
Temperature of charge in degrees, C.
Alkalinity of solution in terms of CaO, pounds per ton.
Mercury in solution, pounds per ton.
SILVER IN SOLUTION, OUNCES PER TON
TIME IN HOURS

FIG. 2—CHART OF AMALGAMATION BARREL CHARGE

The process of mercury recovery consists in leaching the mercuric sulphide from the residue by means of a caustic alkaline sulphide solution, and then precipitating mercury with aluminium.

The residue is caked on a Moore filter and washed free from silver solution with water. The filter is then lowered into a vat containing caustic alkaline sulphide, and this solution is drawn through the cake until all mercuric sulphide is dissolved. Usually 1 ton of solution is used per ton of residue. The resultant filtrate is agitated with aluminium, allowed to settle, and the clear solution decanted. The precipitate is dried, and the fluid mercury separated from the powdered portion, the latter being retorted.

The strength of solution is 4 per cent sodium sulphide and 1 per cent sodium hydroxide. The precipitant is a waste product from aluminium casting foundries, and about ¼ lb. is used per pound of mercury precipitated. Caustic soda is regenerated in the reaction, so that the consumption is but 1/10 lb. per pound of mercury recovered. Sodium sulphide also is regenerated, but there is a mechanical loss of about 20 per cent. The cost of recovering mercury by this process has been about 13 cents per pound.

Effect of Carbon or Graphite on Auriferous Cyanide Solutions.—In the June issue of this journal we presented an abstract of a paper by W. R. Feldtmann on the precipitating action of carbon in contact with auriferous cyanide solutions, originally presented before the Institution of Mining and Metallurgy. In *Bulletin* No. 130 of the same organization we note the following discussion of the subject by PAUL T. BRÜHL, who gives his experience with graphitic ore at the Prestea Block A mine, Gold Coast, Africa. The graphite had the following composition:

Carbon (with S and As)	11.00%
Silicious residue	75.00%
Fe_2O_3	6.56%
Al_2O_3	1.20%
CaO	4.50%
MgO	1.74%

The cyanide solution tested was the same in all cases, and assayed:

Potassium cyanide	0.20 %
Protective alkalinity	0.026%
Gold	61s. 4d.

Experiment 1—Two hundred and fifty grams of the mine graphite, which assayed 51s. 4d., and contained a little iron pyrites and mispickel, were agitated for four hours with 500 c.c. of the cyanide solution. The solution after filtering gave the following analysis:

KCN	0.07 %
P.A.	0.004%
Gold	0s. 4d.

Experiment 2—Two hundred and fifty grams of mine graphite, 50 grm. low grade concentrates, assaying 47s. 6d. per ton, and 600 c.c. of the solution were agitated together for four hours. The solution after filtering gave the following analysis:

KCN	0.07 %
P.A.	0.005%
Gold	1s. 6d.

Experiment 3—Two hundred and fifty grams of mine graphite, 50 grm. rich concentrates, assaying 50s. per ton, were agitated together for four hours. The solution after filtering gave the following analysis:

KCN	0.03 %
P.A.	0.003%
Gold	11s. 6d.

"These experiments indicate the powerful precipitating effect of the mine graphite. The solutions were progressively richer in gold because the sulphides were progressively richer, and the KCN had dissolved to some

extent the gold contents of the sulphides. Solution and precipitation of the gold take place simultaneously, the latter action being the more pronounced of the two in the early stages of the agitation.

"The fact, noticed by Mr. Feldtmann, that there is a load point at from eighteen to twenty-four hours beyond which precipitation is resumed, is one which I also noted when experimenting with slimes. In these experiments the most economic extraction was obtained from each particular charge by agitation for a certain definite number of hours, usually about eighteen; the time necessary varied and depended on the charge. Further agitation caused higher residue values."

In *Bulletin* No. 129, I. M. M., F. Wartenweiler confirms Mr. Feldtmann's conclusions that the precipitated gold is not soluble in any of the strong oxidizing agents, such as chlorine or bromine, and that these do not inhibit precipitation by graphite. Search for other solvents showed that neither sodium hyposulphite nor sodium thiocyanate were effective in redissolving precipitated gold or in preventing precipitation. Mr. Wartenweiler found, however, as did Mr. Feldtmann, that sodium sulphide (0.30 per cent Na_2S) did dissolve precipitated gold in post treatment of residues from cyanidation, and that copper in the form of shavings gave promise of affording a suitable solution precipitant. He found further that an extra treatment could be avoided by adding the alkaline sulphide directly to the cyanide solution for original treatment, and get the same results as by cyanidation plus subsequent treatment with alkaline sulphide. Zinc forms a good precipitant for the solution provided no free Na_2S is left in solution. A peculiar feature of the use of the sodic-sulpho-cyanide solution is that redissolved gold remains in solution for many hours while in contact with the schist, although sulphide may no longer be indicated by qualitative tests.

Comparing the relative gold solvent power of Na_2S solution and the sodic-sulpho-cyanide solution the following empirical statements may be offered:

(*a*) With a clean carbonaceous schist carrying considerable precipitated gold the simple Na_2S solution is the best solvent.

(*b*) With a works concentrator tailing carrying the fairly constant quantity of gold precipitated by the contained schist, the two solutions dissolve equally well the precipitated gold which varies from 2s. to 4s. per ton.

Lead and Zinc

Selective Flotation of Sulphide Minerals.—An Australian invention, recorded in the *Australian Statesman and Mining Standard* for July 22, 1915, provides for the separation of zinc sulphide from the sulphides of lead and iron in the flotation process, by adding to the pulp certain mineral salts which can be decomposed by the acid used in the process, liberating a reducing gas. Thus the inventor, Leslie Bradford of Broken Hill, Australia, uses thiosulphates, sulphites and bisulphites, which, in reaction with sulphuric acid, liberate sulphur dioxide. Or, the gas may be introduced into the pulp in any other manner with equally good results. The net effect is to produce a wetting of the zinc sulphide, causing it to remain in the pulp and be discharged with the gangue, while the lead and iron sulphides float. The separation of the blende from the gangue is then accomplished in a separate operation.

Crushing and Grinding

Scoop Discharges for Tube-Mills.—Though the idea of scoop discharges for tube-mills has received a great deal of attention recently, it is not wholly new. In a paper on the subject by Walter R. Dowling, published in the March, 1915, *Journal* of the Chem., Met. & Min. Soc. of S. Africa, the author illustrates "a scoop discharge with radial arms and perforated plate of 2-ft. diameter," originally installed at the Knights Deep. The drawing bears the date of April 20, 1907. This device was used on account of trouble experienced with backflow of pulp at the feed end of the tube, and was designed to lower the internal level of the pulp. Scoop discharges of improved design have been used at this plant ever since their first introduction.

Some time later Dr. W. A. Caldecott made experiments with an apparatus in which the scoop arms were long enough to cover an effective diameter of 50 in. The scoop consisted of four arms attached to a plate, which, when bolted to the discharge end of a tube, provided four chambers that brought up their quota of pulp as the mill revolved and delivered it to the outlet. A perforated plate was bolted in front of the scoop to prevent the discharge of pebbles. For purposes of experiment in determining the most effective depth of pulp in the mill, without varying the diameter of scoop arms, different effective diameters of perforated plate were used by covering annular areas of the outer portion of the plate. Tests were made at different times at different mills, in order to arrive at average conditions from which conclusions could be drawn.

Assuming that the present average duty, under ordinary conditions, of a standard 5½-ft. by 22-ft. tube-mill is 120 tons of minus 90-mesh product per twenty-four hours, the performances recorded in the tests with scoop discharge showed considerable improvement, the comparative duty being 143 tons. Increase of pebble load to a height materially above the axis of the mill is of little assistance, since the power consumption and pebble wear increase out of all proportion to the increase in quantity of minus 90-mesh product. Thus, in one case, a pebble load of 16.08 tons took 20.04 hp. more to produce only 3.22 tons more than a pebble load of 12.84 tons. The most effective diameter of scoop was found to be 24 in., considering the results obtained and the wear of liner and pebbles. With larger diameter scoop the wear is excessive. There does not appear to be any saving in power in the use of scoop discharge; but the real advantage lies in increased capacity, which is such that five tubes with scoop discharge will do the work of six trunnion discharge mills. Small sand feed decreases the tons of minus 90-mesh product; and as increased sand feeds up to 500 tons do not increase the power consumption of the mill, there is no reason why big feeds should not be given. The most suitable feed of sand per twenty-four hours as a pulp containing 40 per cent moisture, for a 5½-ft. by 22-ft. tube-mill appears to be about 400 tons. The reason for the increased capacity afforded by the scoop discharge is that the level of pulp is lowered and pebbles strike against each other, crushing the adhering grains of sand, rather than falling into a mud bath as under ordinary conditions.

Gas Producers

Wood-Gas Generators.—In the reconstruction of the surface plant at the Sons of Gwalia mine, Australia, wood-gas generators were substituted for charcoal-gas producers and have proved satisfactory and economical. The producers are of the Commonwealth modified downdraft type. Operating data are given by Mr. A. Wauchope in the July *Journal* of the Chamber of Mines of Western Australia.

Firewood in 5-ft. lengths is fed in at the top and the charcoal produced forms a glowing porous mass through which are drawn the products of distillation (i. e., hydrocarbons, steam, etc.) together with the necessary air, thus forming a gas consisting of carbon dioxide, carbon

monoxide, hydrogen, methane and nitrogen. A small amount of oxygen is usually also present in the gas. The following is an analysis of the composition of the gas under normal conditions:

Carbon dioxide (CO_2)	9.7 per cent
Carbon monoxide (CO)	19.5 per cent
Hydrogen (H)	14.1 per cent
Methane (CH_4)	2.1 per cent
Oxygen (O)	0.1 per cent
Nitrogen (N), by difference	54.5 per cent

Calorific value, estimated on composition, 125 B.t.u. per cubic foot.

The charcoal rests on an ordinary fire-bar grate through which the ashes and gas pass into a water-sealed hopper bottom. On a level with the grate there are several doors in the sides of the producer through which the grate is raked free of clinker and ashes. The opening of these doors does not appreciably affect the value of the gas within reasonable limits of time. The volume of gas produced is regulated by the suction of the engine which exerts a pull below the fire grate of the producer ranging from 2 in. to 5 in. of water.

Power costs on those sections of the cyanide mill driven by gas on a horsepower basis are 66 per cent of the power costs of those sections driven by steam. Mulga firewood, having a calorific value of about 7000 B.t.u., is consumed at the rate of from 2 to 2.2 lb. per brake-horsepower-hour.

Fused Silica Ware Made in United States

Things are moving in the chemical industries of the United States. The latest example of the establishment of a new American industry is the announcement that the firm of Lenz & Naumann, Inc., of New York City, has acquired all the American and Canadian patents and manufacturing rights for the system of Dr. Voelker and is equipping now a plant for manufacturing "quartz glass."

Dr. A. Voelker of Cologne, Germany, has been working on the problems of making fused silica ware for many years, as in 1899 he perfected his process and since then, in years of untiring efforts, he slowly developed his large-scale manufacturing methods which to-day make it possible to produce not only ordinary laboratory ware, but articles in such large sizes and such shapes as were considered impossible in former years. The Voelker process permits of the manufacture from ordinary quartz sand not only of opaque but also of transparent (semi-translucent) and translucent quartz. Waterclear quartz glass is made from rock crystal.

This fused silica ware is being introduced by Messrs. Lenz & Naumann under the name of Silicium Dioxyde.

Chain Screen Doors for Oven and Furnace Openings

Everyone who has had to work around ovens and furnaces knows what discomfort has to be endured by the attendants from the heat and gases coming out through the uncovered opening, when the doors are thrown open, and, further, what a chilling effect the inrushing cold air has upon the interior of the furnace and its contents. Doors, however, must be opened; be it to renew the charge, manipulate the contents, or study the interior conditions.

The Wiegand chain screen doors, in the form used mostly around glass, metal and chemical furnaces, consist of a multitude of freely hanging individual strands of steel chain suspended close together from a steel bar in a manner to form a continuous sheet or curtain of chain, not unlike the familiar Japanese screen.

This curtain of chain, hung before the uncovered opening to a furnace and looking like a coat of mail,

FIG. 1—WORKMEN PROTECTED BY CHAIN SCREEN IN GLASS WORKS

effectively hinders the heat, glare and gases from leaving the furnace and the cold air from entering. The loosely hanging strands of light chain are parted with ease and pressed aside by the tools or other objects projected into the furnace, only to fall together again when entrance has been effected.

The holes in the links of chain permit an unhampered view of the interior—in fact, a better survey than under ordinary conditions may be obtained, as the glare is toned down and the effect is similar to looking into the furnace through a piece of wire gauze.

In some plants, when it is necessary to work in front of the uncovered oven or furnace, the workmen are obliged to stand back a great distance from their work and to protect their bodies from the heat and glare with large sheet iron shields which are supported by one hand, while the other manipulates the tools. This seriously handicaps the workman and cuts his efficiency in half. In those plants where the new chain screens have been employed the workman has both hands available for his work and may, with comfort, freely manipulate his tools while standing within a few inches of his work.

FIG. 2—REMOVING HOT POT FROM GLASS FURNACE THROUGH CHAIN SCREEN

When it is necessary to remove a damaged pot in a glass works the chain screen shield is lowered in front of the wall enclosing the pot that is to be removed. The wall is then torn down, and the hot blocks composing the same are dragged through the chain shield and set aside. Now the broken pot is clearly seen in the furnace behind the screen, which closes the opening to the furnace, and the workmen may operate without discomfort close to the pot itself. The absence of heat and glare, coupled with the ability to see clearly what they are doing, enables the workmen to quickly pry up the pot, shove the nose of the pot truck under the pot and drag it through the perfectly flexible and penetrable shield out of the furnace. The strands of chain offer no obstruction to the passage of the truck and pot, immediately falling together again when the pot has passed, closing the opening; thus keeping the heat within and the cold drafts out of the oven or furnace.

When the truck carrying the new pot glowing with heat arrives before the screen shield, protecting the furnace, it is pushed boldly through the same. When once the truck and its pot have passed through the chains the latter close together, protecting the workmen from the radiant heat and the new pot and the whole furnace from drafts of cold air.

The doors are supplied in "automatic" and "non-automatic" forms. The automatic is employed mostly on boiler furnaces, where the opening of the ordinary fire door causes the screen to unroll from a cylinder hung above the furnace opening. The non-automatic, which is much used on ovens and other furnaces, is much simpler in construction. The chains forming the screen are suspended from a bar and may be raised out of the way by a hand chain running through a pulley overhead. When needed the screen is lowered into supporting brackets fixed at the sides of the opening.

In the glass factory, where a very large screen is needed and not more than one opening is made in the furnace at one time, a single screen is made to do duty for a whole furnace. Wherever the wall is to be torn down for the removal of a pot the screen is hung up by its pulley.

These chain screen doors are the result of several years of experimentation, having been first adapted for use on boiler furnaces, where they have been in practical operation for three years. They are made by the E. J. Codd Company, 700 South Caroline Street, Baltimore, Md.

Bihn-Jones Automatic Air Device for Raising or Handling Large Quantities of Liquids

In chemical and industrial plants there are many processes in use requiring the raising or handling of large quantities of liquids, and the use of compressed air has long been considered in this connection as a useful and necessary means of power transmission.

In making use of this compressed-air power for handling liquids, it is necessary to have a blow-case or air-tight chamber into which the liquid is admitted (usually by gravity), and from which it is forced to its destination by the compressed air, the latter being also admitted to the blow-case at necessary intervals. The process consists, therefore, in admitting liquid until the blow-case is filled, then turning off the liquid and turning on an air valve which admits the air. This operation is repeated continuously as long as liquid is to be lifted.

It has long been the effort of inventors to obtain an automatic device which will turn on and off the valves necessary for this operation, and a number of apparatus have from time to time appeared which have been claimed to accomplish this purpose. The chief objection, however, to these apparatus has always been their complicated construction, allowing too great an opportunity for trouble in the mechanical operation.

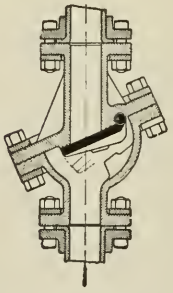


FIG. 1—ANY-POSITION CHECK VALVE

The latest of these devices, known as the Bihn-Jones automatic air device, seems to have overcome all these objections and is very simple in construction and operation. As it attracted considerable and well deserved attention at the recent National Exposition of Chemical Industries in New York City, a somewhat more detailed description should be of interest.

The apparatus consists of two parts. The first is an any-position check valve (Fig. 1), which is composed of two essential parts, namely, a body which contains the valve seat and a flapper which swings on trunnions, thus constituting a valve which will operate in any position. The second piece of apparatus is the automatic air device proper. It is composed, first, of a body in

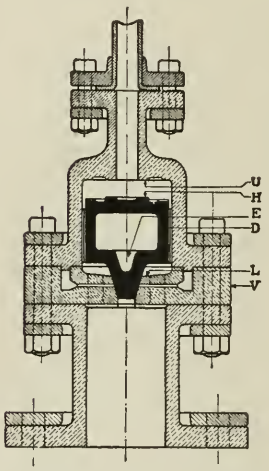


FIG. 2—POSITION OF AIR DEVICE WHEN TANK IS FILLING

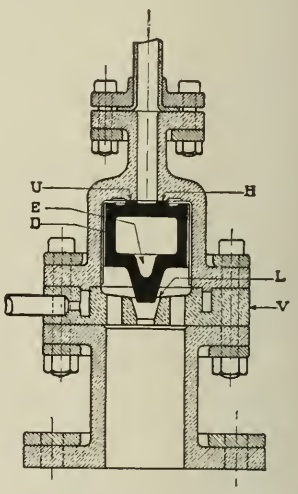


FIG. 3—POSITION OF AIR DEVICE WHEN TANK IS EMPTYING

which is formed the seat of the valve, through which the ports for the admission of compressed air open, the upper portion of the body also containing the exhaust port. Secondly, a disk of a cone and piston type is provided which has two seats, at the bottom a cone

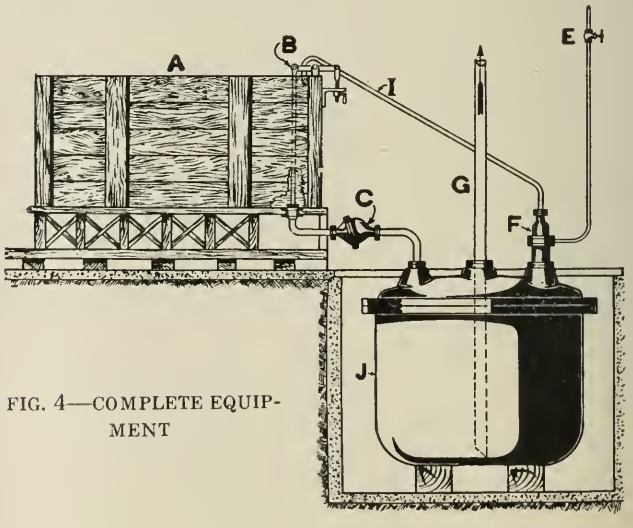


FIG. 4—COMPLETE EQUIPMENT

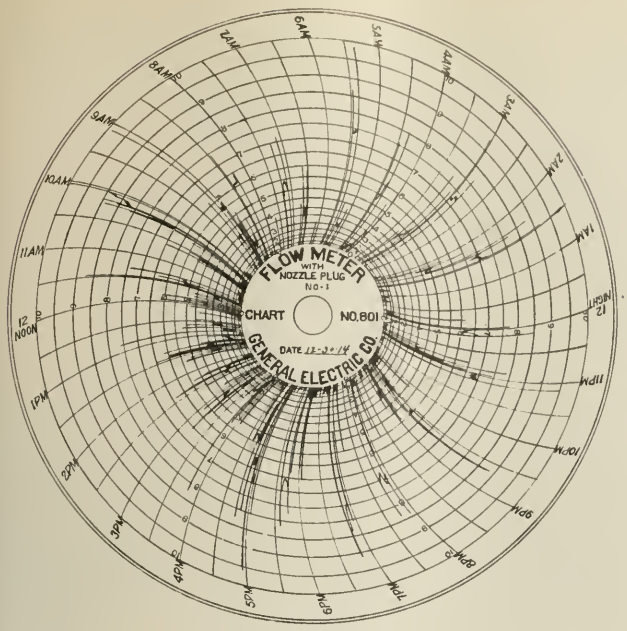


FIG. 5—RECORD CHART

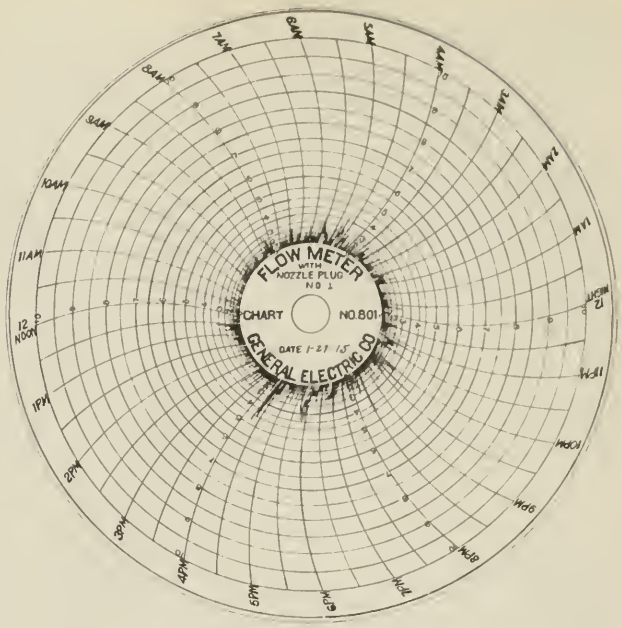


FIG. 6—RECORD CHART

which closes the compressed-air ports and at the top a flat seat which closes the exhaust port. These devices are illustrated in Figs. 2 and 3 respectively.

DETAILED ACTION OF DEVICE

Parts of Air Device.—The air device consists of the following parts:

1. Valve body *V*, which contains a seat *L* controlling the ports for the admission of compressed air, and a seat *U* for controlling the exhaust ports.

2. Disk *D*, of the cone and piston type, the cone *E* being at the base and completes the compressed-air valve. At the top of the disk *D* is a seat *H*, which completes the exhaust-air valve.

The device is actuated by the liquid from storage tank *A*, which flows through the check valve *C* into the blow-case *J*. This liquid rises until it reaches the cone of the disk *D* of the automatic-air device *F*, which it raises, thus permitting compressed air to enter.

The sudden release of the compressed air forces the disk *D* upward against its upper seat *U*, thus closing the exhaust port to vent pipe *I*.

The air pressure is thus prevented from escaping and the pressure exerted on top of the liquid closes the check valve *C* and forces the liquid through discharge pipe *G* to its destination.

When the level of the liquid reaches the opening of the discharge pipe at bottom of blow-case, the compressed air rushes out with the liquid, thus clearing the discharge pipe. The result of the air rushing out the discharge pipe causes a considerable drop of pressure within the blow-case, thus allowing the disk *D* of the air device to drop to its lower seat *L* due to its own weight, simultaneously cutting off the supply of compressed air and opening the exhaust port.

The check valve *C* in the supply line has remained closed during the emptying of the blow-case, but immediately upon the reduction of pressure within the blow-case the check valve opens (due to the head of the liquid in the supply line) and allows the blow-case to refill.

The free air or gas from liquid displaced from blow-case due to refilling is discharged to atmosphere through vent *I*.

The flow of liquid from tank to blow-case may be regulated by a plunger and thumb screw arrangement, as shown at *B* in Fig. 4, or by means of a stop valve. Accordingly, by regulating the supply, the contents of blow-case may be automatically discharged in any specified time.

It will be noticed from the above illustration that the apparatus is entirely outside of the blow-case, no part of it extending within the same, but resting upon a flange collar above the case. It can therefore be readily removed for examination, and its ease of operation may be readily understood.

Aside from being entirely automatic in operation and simple in construction, this device is claimed to reduce considerably the consumption of compressed air which is known to be quite expensive. The charts, Fig. 5 and Fig. 6, were made in a plant where forty blow-cases are in use, seven of which were equipped with the Bihn-Jones automatic air device at the time the test was made. The heavy irregular lines indicate the exact travel of the needle, which indicate the comparative consumption of compressed air. Fig. 5 was produced when the blow-cases were operated by hand, that is, compressed air turned on and off each time the blow-case was discharged, while Fig. 6 illustrates the consumption of air by the seven blow-cases which were equipped with the Bihn-Jones device.

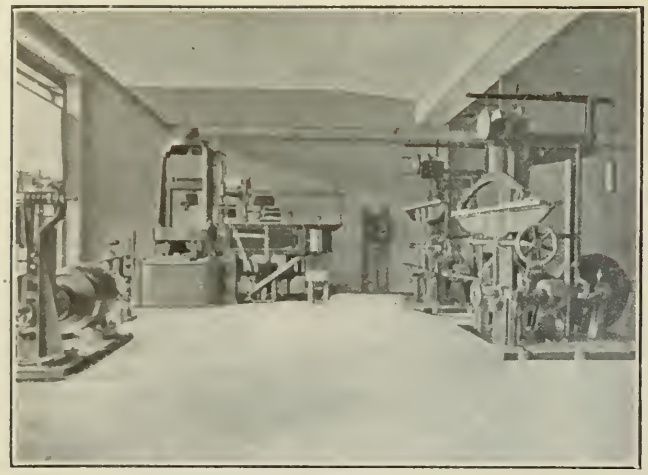
The saving in compressed air is further illustrated by the fact that in the above-mentioned case, in which the forty blow-cases, of 3 to 5½ tons capacity, are being filled and discharged continuously day and night, after the installation of the seven Bihn-Jones automatic air devices one of the compressors was shut down and has since been kept as a reserve unit.

This device is claimed to be particularly adaptable to conditions wherein large bulks of liquids are to be handled, and by properly selecting the material from which it is made it will handle with equal efficiency corrosive material, oily liquids, and, in fact, any material which may be readily caused to flow by compressed air. Its most extensive application is found in handling of sulphuric acid in fertilizer and acid manufacturing plants.

The device is being manufactured by The Schutte & Koerting Company of Philadelphia, Pa.

The Scientific Study of Steel

With a view to taking up the study of the numerous problems in iron and steel on a broader ad more complete scale the Western Spring & Axle Company, whose



TESTING MACHINES IN PHYSICAL LABORATORY

main offices are at Cincinnati, Ohio, have constructed new chemical, physical and microscopical laboratories at Detroit, Mich. This central group of laboratories is larger and more completely equipped than any single member company would be justified in maintaining.

The *chemical laboratory* is completely equipped for the analysis of each shipment of steel as it comes from the mill.

The *physical laboratory* for heat treatment and physical testing contains electric furnaces and a number of testing machines, as shown in the illustration. The machine on the extreme left is a special Upton-Lewis fatigue testing machine. This machine will take any size test bar up to 2 in. wide and ⅜ in. thick and subject the metal to any desired fiber stress and vibrate it at a maximum rate of 1000 r.p.m. It also automatically describes a curve showing the relation between fiber stress and the number of vibrations and the behavior of the steel during the test.

The *microscopical laboratory* is completely equipped for the photographing and examination of metal test specimens, including a recently perfected "inverted" microscope with camera attached having a magnifying range of 20 to 1000 diameters.

The laboratories were instituted not only for member companies, but in their careful planning and complete equipment there has been the thought of a larger usefulness, through co-operative effort with engineers in solving the many problems that arise in this field. The laboratories are in charge of Mr. Erwin C. Arndts, and the company extends a cordial invitation to all who are interested to visit the new laboratories at Detroit.

Personal

Mr. **Charles W. Baker** will take charge of the recently opened New York office of the American Zinc, Lead & Smelting Co. in the Equitable Building. Mr. Baker was recently elected a director of the company.

Mr. **George B. Clark** has sold his Pueblo, Col., assay office and has taken a position as assayer and chemist for the River Smelting and Refining Company, Florence, Col.

Mr. **John Gross**, mining and metallurgical engineer, has recently opened on office at 523 McPhee Building, Denver, Col.

Mr. **E. M. Hamilton**, Mr. **F. A. Beauchamp** and Mr. **S. E. Woodworth** have gone into business together as metallurgists. Their offices will be at 419 Embarcadero, San Francisco.

Mr. **F. E. Marcy** has given up the management of the Salt Lake City office of the Mine & Smelter Supply Company, and will devote his time to the promotion of the Marcy mill, which is made by that company.

Mr. **F. E. Parks** will become manager of the Minnequa works of the Colorado Fuel & Iron Company, succeeding J. B. McKennan, who becomes general manager of the company.

Mr. **James Coles Roberts** of the U. S. Bureau of Mines, Denver, Col., has been selected for the Joseph Austin Holmes Professorship of Safety and Efficiency Engineering at the Colorado School of Mines.

Mr. **L. Selmi**, chemist and metallurgist of the Otis Steel Co., Cleveland, Ohio, has resigned to take charge of the chemical and physical laboratories of Corrigan, McKinney & Co. of Cleveland, a new steel plant.

Mr. **R. G. Williams**, safety engineer of the Norton Company, Worcester, Mass., has succeeded Mr. F. C. Schwedtman as chairman of the committee on accident prevention of the National Association of Manufacturers.

Mr. **F. O. Williamson**, representative of the Hardinge Conical Mill Co., T. L. Smith Co., and Smith Engineering Works in Chicago, is taking a trip through the Western mining districts.

Book Reviews

Molecular Association. By **W. E. S. Turner.** Octavo, 170 pages, 6 illus. Price, $1.40. New York: Longmans, Green & Co.

This is one of the monographs on inorganic and physical chemistry, edited by Dr. Alexander Findley. The topics principally dealt with are molecular association in gases (a comparatively simple field), of dissolved substances (an uncertain subject), the molecular complexity of the liquid state (an almost unknown territory), and of the solid state (a collection of speculations). While the monograph may be styled "satisfactory" because it presents nearly all that can now be said on the subject, yet it is necessary to say that the subject itself (aside from the topic of gases) is in a highly unsatisfactory condition, and there is not much gratification in store for the reader who peruses the book with the thought of learning something definite about the molecular state of solutions, liquids and solids. The author himself appreciates this situation, saying at one place: "There is great need of some guiding and reconciling principle like Avogadro's hypothesis." The reader will agree with him.

Methods in Metallurgical Analysis. By **Charles H. White.** 356 pages, 106 illus. Price, $2.50. New York: D. Van Nostrand Company.

Professor White writes from the standpoint of his experience in the Harvard School of Mining and Metallurgy. This is a text-book of quantitative analysis for metallurgical students. It is plainly written, in simple, direct style, giving the information needed in the fewest possible words.

It is an admirable repository of methods, so abridged as to read almost like recipes. In fact, this is the chief lack of the book, the frequent absence of reasons for the steps described. Assuming that the book is to be used under the careful supervision of a capable instructor, who will explain the *why* and *wherefore* (and thus, in reality, instruct and educate the student), it is an admirable laboratory manual; but for a man working without such assistance it would be an unsatisfactory guide.

It deserves a place in the commercial laboratory analyzing ores, metals or alloys, but the information is rather elementary for this purpose and must be used discriminatingly.

Metallurgical and Chemical Engineering

A Consolidation of
Electrochemical and Metallurgical Industry and Iron and Steel Magazine

Vol. XIII NEW YORK, DECEMBER 1, 1915 No. 15

Published Semi-monthly on the First and Fifteenth of Each Month by the

McGRAW PUBLISHING COMPANY, INC.

James H. McGraw, President.

A. E. Clifford, Secretary. John T. DeMott, Treasurer

239 West 39th St., New York.

Telephone, 4700 Bryant. Cable Address, Metcham, New York.

Rocky Mountain Office.....421 Boston Bldg., Denver, Col.
Pacific Coast Office.....502 Rialto Bldg., San Francisco, Cal.
Chicago Office.....Old Colony Building
Cleveland Office.....Leader News Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; *all other countries,* $2.50. (*European exchange,* 10 *shillings,* 10 *marks,* 12.50 *francs.*)

Copyright. 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for December 1, 1915

EDITORIAL:
Flow-Sheets of Organization 879
Productive Capacities in the Iron and Steel Industry 880
Flotation and Cyanidation 880
Imports and Exports of Steel 881
READERS' VIEWS AND COMMENTS:
Wet Ore in Charcoal Blast Furnaces. By R. H. Lee 882
The Electric Furnace in the Foundry. By R. C. Gosrow. 882
Award of Nobel Prize in Chemistry to Theodore W. Richards .. 884
The Failure of the Hull of the "Sea Call" 884
Coming Society Meetings 884
Electrochemistry and Lighting (Report of Meeting of New York Section of American Electrochemical Society) 884
Co-Operation Between University and Industry (Report of Meeting of New York Section of American Chemical Society) 885
American Institute of Mining Engineers (New York Section Meeting) 887
Coal and Iron in Nova Scotia and Newfoundland (Report of Meeting of Mining and Metallurgical Society of America) 887
The Western Metallurgical Field 887
The Iron and Steel Market 889
Non-Ferrous Metal Market 890
Alumina in Steel. By George F. Comstock 891
Solution Stratification as an Aid in Purification of Electrolytes. By Francis R. Pyne 895
Determination of Mercury in Amalgamation Tailing 896
Flotation at the Consolidated Arizona Smelting Co., Humboldt, Ariz. 897
The Treatment of Sewage by Aeration in the Presence of Activated Sludge. By Edward Bartow 901
Columbia Section, American Institute of Mining Engineers ... 904
Equipment of Arizona Smelters 904
Thermal Principles of the Blast Furnace II. By J. E. Johnson, Jr. 905
Solution of Smoke Fume and Dust Problems by Electrical Precipitation. By Linn Bradley 911
The Electric Arc in Vapors and Gases at Reduced Pressures. By W. A. Darrah 915
The Development of Refined Tars for Use in Road Construction and Maintenance. By Philip P. Sharples 918
Society of Chemical Industry. Report of N. Y. Section Meeting 921
The Physics of the Photographic Process. By C. E. Kenneth Mees 923
Recent Chemical and Metallurgical Patents 923
Synopsis of Recent Chemical and Metallurgical Literature 924
Improved Apparatus for Photomicrography of Metals 928
Thermit Welding of Cam Shafts 929
New Flotation Testing Machine 930
Sampling Lead Bullion 930
A New Die Casting Metal 931
Personal 931
Obituary 931
Digest of Electrochemical U. S. Patents 931
Book Reviews 932

Flow-Sheets of Organization

In his opening address as Honorary President of the recent International Engineering Congress, General Goethals enlarged on the subject of organization as a factor in carrying engineering projects to a successful issue. The ability to create and maintain a loyal and efficient organization of the human element in any project is one of the first essentials to success. With it there is harmony and economy; without it, confusion and waste.

Borrowing an analogy from a well-established metallurgical custom, a flow-sheet of organization will be found quite as useful in visualizing the proper relations between the different departments of a company, as a flow-sheet of ore-treatment is in illustrating the different steps in a process. The very act of reducing the details of an organization to diagrammatic form will clarify the scheme in the mind of the chief, crystallize a more efficient method of transacting business through subordinate channels, and establish responsibility throughout the entire force.

It is a well-recognized and fundamental principle of organization that definite authority must be delegated if responsibility is to be demanded, just as in military affairs rank is established to insure command. Once established, the integrity of the organization must be maintained, and loyalty becomes the important consideration. The individual must recognize that the organization represents a purpose or object greater than any one factor in it, which can be attained only by harmonious and co-operative effort.

The more diverse the activities of an organization the greater the need for a well-established flow-sheet of authority and responsibility. For instance, some mining and metallurgical concerns carry on the three operations of mining, concentrating and smelting. It is self-evident that each of these operations is but a single factor in the accomplishment of a certain purpose, and ultimate success requires the proper correlation of work in the several departments. Loyalty demands that, so far as possible, the mine shall meet the requirements of the mill, and the mill of the smelter. Any attempt on the part of one to make a record at the expense of the other defeats the ultimate object.

Within a department the status of the individual must be recognized by his subordinates and superiors, orders being transmitted down the line of authority, and grievances, complaints and suggestions upward through the line of responsibility; provided, that in the latter case a channel be open to the head of the organization if the established flow-sheet is rendered

ineffective for a subordinate through unfairness on the part of an immediate or intermediate superior.

All these and many other features of organization and management will become apparent, and their importance more fully realized, if delineated in the form of a flow-sheet. Every factor in the organization will understand his position and appreciate his importance, with the result that an *esprit de corps* will be created that will overcome many obstacles tending to wreck an otherwise well-conceived and meritorious project.

Productive Capacities in the Iron and Steel Industry

The present general advance in iron and steel-market prices began at the end of last December, for on the first day of this year the regularly quoted market on bars, plates and shapes advanced from 1.05 cent to 1.10 cent. Throughout the first half of the year these commodities, and practically all other finished steel products, advanced in a moderate way. The average advance was about $2 per ton. The demand was steadily increasing, though it was not until July or August that it was sufficient to engage the full capacity of the steel industry. During the first half of the year, however, there was no general advance in pig iron.

By the first of September steel, merely as steel, had become scarce, while pig iron was still plentiful. The condition was precisely the one observers had not expected. Since 1912, when pig iron and steel prices were fairly well aligned with each other, there had been much more new construction of steel-making capacity than of blast furnaces, and from this showing pig iron should have grown scarce first. Like many other things, a condition could be explained when realized, although it could not be predicted. The blast furnaces individually were making better records than ever before, and the country's capacity, based on the performance of individual furnaces in the past few months, appears to be nearer 40,000,000 tons a year than the 35,000,000 tons estimated not so long ago. Furthermore, the demands of the foundry trade were light and more merchant furnaces served the steel instead of the foundry trade.

A new turn seems to have been given the kaleidoscope, and while steel prices have not ceased advancing by any means the pig iron market is now advancing very sharply. It is estimated that the average advance in pig iron during November has been not less than $1.50 a ton, whereas during all the movement that preceded there was an advance of only about $2.50. Nevertheless the foundry trade is still not busy and there is reason to believe that should the buying of foundry pig iron become as heavy as has been the buying of steel the demands upon the merchant furnaces could not be met. Blast furnace capacity might then be found to be deficient with respect to steel-making capacity, which would fit expectations entertained until recently.

There is so much news in the iron and steel trade, even in dull times, and events move so rapidly, that it is seldom long range comparisons are made. Comparison of pig iron and steel prices suggests a very interesting one. Pig iron has now advanced about $4 a ton, while finished steel prices have advanced more than $10 a ton. It is not more than ten years ago that in most quarters the impression prevailed that the strength of a large steel-producing interest lay chiefly in its control of raw materials, and iron ore in particular. Should materials become scarce those that lay closest to being in the raw stage should advance the most. Such was the case in the market movement of 1905-6-7, when Bessemer pig iron advanced to $23.25 and basic to $23 at Valley furnaces, while the large mills did not quote above 1.70 cent for plates and shapes and 1.60 cent for bars. On Nov. 18 last the Carnegie Steel Company advanced its price on bars, plates and shapes to 1.70 cent, but on that day Bessemer pig iron was $16.75, Valley, and basic iron $16. The spread between pig iron and finished steel was $7 wider than was the spread when the 1907 market was at its top. Ore is less important and steel making and finishing capacity more important.

Flotation and Cyanidation

The success of flotation as a concentration process is bringing in its wake a number of interesting problems in metallurgy, not the least of which relates to the cyanidation of flotation products—concentrates and tailings. In fact the future development of flotation may have an economic bearing on the continued use of the cyanide process in some places.

It has long been customary in many cyanide mills to combine table concentration with cyanidation for a variety of purposes: the removal of a refractory portion of the ore as a concentrate for smelting, followed by cyanidation of the tailing; the production of a barren tailing which is discarded, while the concentrate is cyanided; or, the separation of a concentrate for regrinding, after which it is again combined with the tailing for cyanidation. These processes have become standard and their details are well understood.

With the introduction of oil flotation a question naturally arose as to the possibility of cyaniding its products just as table products had been treated. At present it does not seem at all certain that the idea is easy of general accomplishment. In some cases it has been possible to substitute oil flotation for gravity concentration and cyanide the concentrates without difficulty. On the other hand, however, one metallurgist experienced in cyanidation has said that thus far he has been unable to cyanide raw flotation concentrates. And in another case where table tailing is being successfully treated by cyanidation, it has been impossible, at least in preliminary tests, to cyanide the tailing from the same ore when concentrated by flotation.

The difficulty is not regarded as insurmountable, and in all probability the problem will be solved in the extended research that is now under way. A rare opportunity is offered to study the physical and chemical effect of a small quantity of oil to see how far it may inhibit the chemical and electrochemical phenomena involved in cyanidation. It is not in concentrates alone that oil may cause trouble, for in the use of the more water-miscible oils, such as turpentine, appreciable quantities may exist in the tailings. Again, it is possible, through selective action, that in the treatment of

some ores flotation may fail to remove as a concentrate the refractory portion which gravity concentration handles successfully, thereby leaving in the tailing a valuable constituent not amenable to cyanidation.

With regard to flotation as a menace to the continued success of cyanidation in some districts, it has been suggested that the latter process may find it difficult to maintain permanently its present supremacy. The economic balance may swing in favor of a combination of flotation and smelting, as against cyanidation. Capital and operating cost would seem to favor flotation, and with a normal recovery and favorable smelting rates it is quite possible that flotation could appear as an active competitor to cyanidation. The cost of flotation oils is increasing, due to the unusual demand for tar products and the limited production of wood oils. But the oil cost is not the major item in the total cost and an increase in price will not be prohibitive.

Imports and Exports of Steel

Few industries have experienced such changes in the character of their foreign trade as has the iron and steel industry, and quite naturally, since substantially all the countries apart from the United States that produce iron and steel are at war with each other. While iron and steel is one of the most nearly self-contained of all industries it is not wholly so, and thus the country that exports some descriptions of material usually imports others. The United States, for instance, has had its imports of iron ore cut down. The latest import and export statistics available are those for the month of September and the nine months of the calendar year ending September, hence a comparison, to illustrate war conditions, is naturally made between the first nine months of the years 1913 and 1915 respectively. There was no very great difference in the industrial activity in the two periods, the production of pig iron in the United States being 15 per cent less in the later than in the earlier pig iron. Imports of iron ore, however, decreased from 1,916,733 tons to 971,098 tons, or practically 50 per cent, there being decreases in imports alike from Sweden, Spain, Canada and Cuba. There were also great decreases in imports of pig iron and ferromanganese. Imports of unfinished steel, chiefly high-grade alloy steel, decreased from 18,000 tons to 9300 tons. Imports of machinery, cutlery and the like suffered large decreases.

Our exports of iron and steel and manufactures thereof are always vastly greater than our imports of corresponding material, the calendar year 1913 showing imports (not including iron ore) of $33,601,985 against exports of $293,934,160, nearly nine times as great. Naturally one expects to find great changes in the iron and steel export trade, and a glance at the statistics does not disappoint him. By setting in antithesis some of the items one may see quite clearly a few of the changes that war has wrought. Comparing, as before, figures for the first nine months of 1913 and 1915 respectively, exports of agricultural implements, hitherto taken largely by Europe, have decreased from $27,622,594 to $10,371,379, while exports of breadstuffs have increased from $166,848,067 to $423,360,972. Europe must have the food ready to eat. The wheelbarrow yields to the motorcycle, the wagon to the motor truck and the carriage to the passenger automobile. Exports of wheelbarrows, push carts, etc., decreased from $598,648 to $232,391, while the number of motorcycles exported increased from 3459 to 11,859; wagons exported decreased from 16,980 to 5949, while motor trucks increased from 778 to 17,269; carriages decreased from 13,458 to 1139, while passenger automobiles increased from 20,175 to 31,036. This is a modern war and there is nothing slow about it. Exports of railway cars to North and South America and Japan decreased from $12,883,673 to $1,234,168, or 88 per cent, while exports to "other countries" undoubtedly Europe almost exclusively, increased from $618,773 to $1,721,620, or 180 per cent.

Exports of cash registers decreased from 33,064 to 11,920, but horseshoe exports increased from 950 tons to 14,000 tons. Printing press exports decreased from $2,031,774 to $1,065,529, but exports of metal working machinery increased from $11,980,778 to $30,844,199. From the ordinary steel mill products antitheses can readily be picked out. Steel bars, used chiefly for the manufacture of shells, increased from 164,000 tons to 300,000 tons, while structural iron and steel, not particularly useful for war purposes, decreased from 309,000 tons to 169,000 tons.

The government export statistics customarily give the principal countries of destination in the case of important exports, but as the classification was established before the present conditions arose it is not well fitted for the presentation of illuminating statistics. In the case of plain and Barb wire, for instance, the adopted classification is: Canada, Mexico, Cuba, Argentina, Brazil, other South America, British Oceania, British Africa and "other countries." The exports to the countries named increased from 124,000 tons to 145,000 tons, their total imports being undoubtedly decreased, but a much larger proportion being drawn from the United States, while the "other countries" increased their imports from 18,000 tons to 196,000 tons. There is reason to infer that plain and barb wire has been taken for war purposes at the rate of 225,000 or 250,000 tons a year.

Exports of such iron and steel commodities as are returned by weight, including scrap, pig iron, unfinished steel, rolled iron and steel, cast and wrought pipe, nails, wire, etc., but no machinery, have been as follows in gross tons:

1912	2,948,466
1913	2,730,681
1914	2,085,511
First quarter, 1915	458,470
Second quarter	842,291
Third quarter	1,166,667

Thus these exports have reached a rate of 4,650,000 gross tons a year. Iron and steel used in the manufacture of shells, machinery, automobiles, railway rolling stock, etc., undoubtedly amounts to more than the equivalent of 2,400,000 tons a year, so that iron and steel to the extent of more than 7,000,000 tons a year is involved in the direct and indirect exports.

Readers' Views and Comments

Wet Ores in Charcoal Blast Furnaces

To the Editor of Metallurgical & Chemical Engineering:

Sir:—I read with a great deal of interest Mr. Johnson's working out mathematically the effect of wet ores in charcoal practice. The actual fact that filling wet ores was injurious to the efficiency of charcoal furnaces both in output and fuel consumption has been a well-known fact ever since iron was made with charcoal in blast furnaces, and the main reason, viz., that the stack heat was lessened, was also perfectly well understood.

In my own experience, when quite a young man, I often had occasion to notice the tremendous difference in furnace working between wet and dry ores.

One of the furnaces under my charge was a small cold-blast charcoal furnace using soft fossil ores from the company's mines. An attempt was always made to have a sufficient supply of ore on hand for six months' use at least. This ore was unloaded from the mine cars on piles, not over 6 ft. or 8 ft. high, and under a shed with open sides. The ore merely being protected by a roof.

The ore in the course of time became air-dried, and the moisture would not average over from 4 to 6 per cent. The dried ore itself averaged about 45 per cent in iron with 15 to 18 silica and 4 to 6 alumina.

The burden was 600 lb. ore, 30 to 40 lb. limestone on a charcoal unit of 18 bu., or 360 lb. well-mixed coal.

Sometimes, however, the ore stocks would run out and we would be compelled to use ore direct from the mines, often running as high as 15 and even 20 per cent of water. In such cases the burden would have to be cut to 525 and even as low as 500 lb. with a corresponding reduction in iron, and the iron generally a grade or two lower than made with the full burden of dry ore. I have often seen the temperature of the escaping gases drop to 120 deg. Fahr., so cool, in fact, that the hand could be held in the gases issuing from the open top. For they were so wet that they would not ignite until they went into the boiler combustion chamber, where a couple of logs of wood had generally to be kept burning to light the wet gases.

This was the common practice and experience all over central Pennsylvania where fossil ores were used, and I remember seeing at Mount Alto several large ore roasters which the superintendent, Col. John Weistling, had built to dehydrate the ordinary brown hematite (limonite) ores used at this plant. These ores were the average brown hematite found throughout Pennsylvania and Virginia running after washing about 40 to 45 per cent in iron, and containing 10 to 13 per cent combined water, very little if any sulphur, and no carbonic acid. He roasted these ores simply to drive off the moisture, as they were amply porous for easy reduction, and he told me he had found by experience that the use of roasted ore made a reduction of from 10 to 12 per cent in his fuel. It was also a common practice throughout central Pennsylvania at the old charcoal furnaces to pile the brown hematite ores in piles sometimes several hundred feet long, 8 to 10 ft. high and 20 ft. wide. These piles were formed by a layer of cordwood and kindling on the ground, then about a foot of ore, 2 to 3 in. of charcoal breeze, 1 ft. of ore and so on to the top. The pile was lit at one end and used while piling was going on at the other. Whenever roasted ore ran out and raw was used it was necessary to cut the burden.

Pennsylvania Steel Company,
Lebanon, Pa. R. H. Lee.

The Electric Furnace in the Foundry

To the Editor of Metallurgical & Chemical Engineering:

Sir:—For some time past, the various technical journals have contained articles on "the electric furnace in the foundry." Each author of these articles has given his opinions and experiences, with the uncorroborated experiences of others.

But with all this, and in summing up the substance of the literature the vital question stands out, "Why is electric-process steel superior to steel made by other processes?"

To answer this question we can find a considerable amount of literature. Good authorities say that the conditions of melting and refining in the electric furnace, out of contact with the flame and gases, and in a neutral or reducing atmosphere, contribute to the superiority of the product. Others state that the high temperature and the reducing conditions make a superior product. Numerous convincing reasons are given by the manufacturers of electric-steel furnaces. Among them we can cite the following from their advertisements in the technical journals: "Crucible steel quality, with maximum of uniformity," "will produce high-grade tool steel from pig and ore," "excellent castings," "low cost of upkeep in producing every grade of iron and steel," and many more that have the same tone. On the other side the operators have arranged themselves, with an equally imposing lineup of statements. As their argument for superiority of electric-process steel they give: "Homogeneity," "absence of segregation," "elimination of oxides," "complete control of elements," "great tenacity to finished product," "high elastic limit," "high ratio of elastic limit to ultimate strength," "ready response to heat treatment," "ability to obtain very hot metal," and many more that I have not compiled.

In the capitulation of all this literature, it appears that the manufacturers of the electric furnaces, and the operators of the electric process have come to the same general conclusion, namely, that "the electric process for steel outclasses anything yet produced for an as-near-to-perfect product."

My remarks might have the tone of an antagonist to the electric-steel process. But quite to the contrary. What I am endeavoring to bring out is the point, why the electric-steel process *necessarily* should outclass anything ever produced in an as-near-to-perfect product.

Primarily, the melting chamber is enclosed from outside atmospheric effects. The melting down is carried on in a slightly oxidizing condition. The refining is decidedly reducing and neutral. No oxidizing gases have contact with the bath, as in the processes using a gas flame for melting. The protection of the metal from contaminations taken up from the gases, as in gas-fired furnaces. The electrodes give no contaminating elements to the metal. The temperature can be controlled by regulating the amperage going to the furnace. These facts from a physical standpoint of advantages of the apparatus have a great effect on the chemical properties of the product.

Some operators and owners of the electric furnace for steel have made statements that "they did not have the anticipated results from the furnace they put in their plant." Others said "they had trouble in understanding the electrical machinery connected with it." And still another stated "he was always afraid some-

thing was going wrong with the juice." One owner told me it was difficult to sell their castings, when another process at less cost was in the field, making cheaper castings. As a general thing, users of steel castings and steel are not looking for something cheaper, but something better, to fill their requirements.

The first essential in any furnace is the proper design of the apparatus, to carry out economically and satisfactorily the duty imposed upon it. Most foundrymen are men of limited technical training, and do not readily take up a complicated contrivance, especially an electrical one on a furnace. This feature is a very commendable one to the manufacturers of electric furnaces in America. Simplicity of the American-made furnace is characteristic. With such an apparatus the foundryman can manipulate the furnace without days or weeks of instructions.

A furnace might be supplied to a customer to handle a certain maximum size scrap. A large supply, or a large field to draw from, might exist at the time the furnace was installed. Eventually this supply of scrap is consumed, and a less desirable material must be utilized for the furnace. Possibly furnace alterations become necessary, causing an extra expenditure to the owner. The operator may not be able to operate his furnace as he did when he had the desirable and satisfactory scrap available. His costs increase, other irregularities present themselves such as, time to charge up, melting down, refining. Indirectly he finds that his production has decreased slightly.

An instance of this took place at a plant at which I was. The furnace was originally built to handle scrap of a certain maximum size. This pertains to the size of the charging-door openings. Small shovel scrap and such scrap as could be charged easily, had been available for some time. Eventually this desirable scrap became depleted. The management purchased an 80-ton lot of scrap split-steel gears, weighing approximately 120 lb. each, and 20 in. in diameter. Each gear was bolted with two 1½-in. steel bolts. The gears as they were were too large for our furnace. Consequently each gear had to be cut apart by taking off the two nuts. This necessitated extra expense in handling the scrap; the large chunks took a longer time to charge; the time of melting down was increased, and the output of the furnace for a given time was decreased. The cost per ton increased. Here the proper scrap was the vital point in the economy of the operations.

Right here I wish to state that, in my opinion, the "sesame" to making high-grade superior steel by the electric process, both economically and satisfactorily, is dependent on the scrap and the purity and condition of the materials charged into the furnace.

In using the all-scrap process, which I consider the simplest of processes for electric-steel castings, the scrap must be given careful attention. In packing crucibles for the crucible process, only the cleanest and most desirable selected material was used. Punchings of medium open-hearth steel were riddled to take out all dirt and loose rust. Manufacturers of crucible steel made a special iron for their crucible plants, to get the best materials for the process. Careful supervision during melting and careful selection of the materials charged produced a high-grade superior-quality steel. Up to the advent of the electric-furnace process, crucible steel was considered without a competitor. But without the careful selection of the melting scrap, crucible steel would not have been what crucible steel is known to be.

Electric steel now has the same chance that crucible steel had. The materials must have the necessary attention to guarantee a product from them. Unless the cleanest and best selected scrap is utilized for the electric furnace, electric-process steel will not fulfill the claims made for it.

When a manufacturer of castings by the electric-furnace process made the remark that he had not found the electric furnace what had been claimed for it, I questioned him on several points. Among them I asked to see his scrap. He showed me his stocks. The purchased scrap was out in the weather, coated with rust and dirt. Layers of rust peeled from the material. His scrap castings were sandy and dirty. The fillets of the castings contained considerable sand, as well as sand sticking all over them. The sprue was likewise sandy and unclean. Core sand was still in the cored holes of the castings. And this scrap went to the furnace just as I saw it. The punchings, of which there was a large stock, were shoveled from the floor, and, sand and dirt and rust mixed with them, taken to the furnace.

With such materials charged no process will turn out a high-grade superior product, especially what is desired for a steel casting. Every bit of dirt put into the furnace must rise through the molten bath and be taken off by the slag. Unnecessary dirt charged takes unnecessary time to finish the heat. Time in the electric process means power consumption, and power consumption means dollars and cents. Eventually a heat is poured exhibiting dirt holes and entrained slag in the castings, and the furnace and the process is condemned. The presence of iron oxide, as rust on the scrap charged, increases the labor of "killing" or deoxidizing the metal. Ferrous oxide is very soluble in a melted steel bath. During the melting down of a cold charge of scrap, oxidation of the metalloids and metal takes place. These metallic oxides must be reduced, the solid product brought to the surface and the gaseous products allowed to escape. By adding an unnecessary amount of oxides from the scrap an unnecessary amount has to be reduced in cleaning the metal. This increases the time of making a heat, because unnecessary labor and time has to be expended to get the metal ready to pour. As the atmosphere of the melting chamber during melting down of the charge is oxidizing, sufficient oxidation goes on to oxidize phosphorous, etc., without adding any outside oxidizer.

By proper protection against the weather, sand blasting of the extremely dirty and heavy pieces, and rattling of the lighter shovel scrap, a clean and acceptable charge can be provided for the furnace. This might militate against costs. But with a superior product a better price can be obtained for it.

Absence of segregation, elimination of oxides can be controlled to a considerable extent by careful observance of the scrap charged. The presence of manganese sulphide has considerable to do with the defects of segregation. Much of the so-called "blowholes" are due to the presence of manganese sulphide. The oxidation effect and the presence of oxides might exist after the metal has been tested and found to be deoxidized. The extremely high temperature of the electric furnace causes the metal to become considerably superheated. At the time of pouring from the furnace into the ladles a state of oxidization could exist, in which the metal becomes oxidized and gets "wild." Then the purging of the molds shows a gas evolution in the metal.

In conclusion, I consider the use of clean scrap to be the most essential and primary factor toward turning out a superior and high-grade product from the electric steel furnace. With the small capacity per heat, and the necessity of selecting clean and desirable scrap for each heat, the electric-furnace process for steel making can be made to give a product superior to anything on the market, and at a price that can compete with other processes.

R. C. GOSROW.

Heroult, California.

Award of Nobel Prize in Chemistry to Theodore W. Richards

The award of the Nobel prize for 1915 to Prof. Theodore W. Richards of Harvard University has been announced. The work of Professor Richards on the atomic weights is well known and is generally recognized as the best work which has been done on this subject. With the help of assistants he has so far revised the atomic weights of about twenty elements. The results were published in various papers, published in the *Journal* of the American Chemical Society and elsewhere, and in a book "Experimentelle Untersuchungen über Atomgewichte" 1909. He has made many other contributions to physical chemistry, thermochemistry and electrochemistry. Professor Richards has been connected with Harvard for a long time, having taught there since 1889. In 1901 he was offered a chair in chemistry at the University of Göttingen, Germany, but declined, deciding to stay at Harvard. In 1907 he was visiting professor at the University of Berlin and in 1914 was president of the American Chemical Society.

The Failure of the Hull of the Sea Call

In view of the publicity which has been given the failure of the hull of the splendid schooner Sea Call, belonging to Alexander Cochran of Yonkers, N. Y., it is timely to have a statement from the Supplee-Biddle Hardware Company, Philadelphia, Pa., dealers in Monel metal, as the hull of the Sea Call was composed of Monel metal below the water line. This statement of the causes of the failure, given in the November number of the Supplee-Biddle *Bulletin*, points out that the failure was due to electrolytic action between steel as negative pole and Monel metal as positive pole.

Steel plates were used above the water line, and by mistake a few steel rivets were used in some of the Monel metal plates below the water line. It was the eating away of these rivets which first showed the corrosion that was taking place. The Monel metal was not affected. The most rigid examination was made of this hull, in view of the importance of the question, and it was concluded that had the hull been made only of Monel metal corrosion would not have taken place.

The hull was hauled out of water on Aug. 24 in the presence of a number of engineers representing prominent builders and owners.

The most exhaustive examination was made by these gentlemen to satisfy themselves and the companies they represent of the facts. It was therefore gratifying to every one interested in the production and use of Monel metal to know of the perfect condition of Monel metal in resisting the galvanic action that had destroyed steel and rendered an investment said to be half of a million dollars practically worthless.

SECTION SHOWING STEEL PITTED AND MONEL SHEET UNINJURED

The examination showed that the steel section under the water had seriously corroded. One of the most noticeable instances was that of the fine steel rib of the rudder frame. The interior framing of the vessel was of steel and this was, of course, connected with the Monel metal plates which made it possible that under the action of the bilge water corrosion would extend to all this steel work until the inner frame of the yacht was in a dangerous condition.

If the fault lay with Monel metal and there was danger of corrosion and rusting away it can readily be seen that its future as a roofing and as a general utility metal would be killed. It was on this account that the exhaustive study of the case was made to determine exactly where the responsibility lay. It is therefore gratifying to its makers and to the judgment of the various engineers concerned, that the cause of the trouble and resulting loss was found entirely outside of this valuable natural alloy and due alone to the combination of steel with the action of salt water.

Coming Society Meetings

A joint meeting of the New York Sections of the American Chemical Society, American Electrochemical Society and Society of Chemical Industry will be held in Rumford Hall, Chemists Club, on Friday evening, Dec. 10. The subject will be a continuation of that taken up at the last meeting of the American Chemical Society and also of the Society of Chemical Industry, viz.: Research and Chemical Industry. This will be Boston "Tech" night, the first A. C. S. meeting having been given over to Columbia University.

The winter meeting of the American Institute of Chemical Engineers will be held in Baltimore, Md., Jan. 12-15. A number of excursions to some of Baltimore's important industries will be arranged and the experimental laboratories of Johns Hopkins University and the U. S. Naval Academy at Annapolis will be visited.

The second Pan-American Scientific Congress will be held in Washington, D. C., Dec. 27 to Jan. 8. One of the nine sections will be devoted to mining and metallurgy, economic geology and applied chemistry.

The spring meeting of the American Electrochemical Society will be held in Washington, D. C., from April 27 to 29, 1916.

Electrochemistry and Lighting

Joint Meeting of New York Section of American Electrochemical Society and Illuminating Engineering Society

A very interesting joint meeting of the New York Section of the American Electrochemical Society and of the Illuminating Engineering Society was held on Thursday, Nov. 11, 1915, at the United Engineering Societies Building in New York. The program of the evening was electric conduction through gases in its relation to light production. Dr. **Colin G. Fink**, of the Edison Lamp Works, Harrison, N. J., chairman of the New York Section of the American Electrochemical Society, presided.

UNSTABLE STATES OF THE ARC

The first paper was presented by Professor **W. G. Cady**, of Wesleyan University, on "Unstable States in Arc and Glow." This paper, which we published in full in our issue of Nov. 15 (page 866), was illustrated by lantern slides and at its conclusion Professor Cady

made some very interesting experimental demonstrations of the singing arc, showing the possibilities of exact tuning. The paper was discussed by Dr. Moore, Mr. Mott and Dr. McKay.

A TRUE DAYLIGHT ARC LAMP

Mr. D. McFarlan Moore of the Edison Lamp Works, Harrison, N. J., followed with an elaborate and long paper on the latest developments of Moore tube lamps. One of his most interesting exhibits was a *neon tube* lamp, but the main part of the paper dealt with his *carbon dioxide tube lamp for color matching.* He employs in it a new principle for automatically replenishing the supply of gas within the tube as the gas is used up during the operation of the lamp.

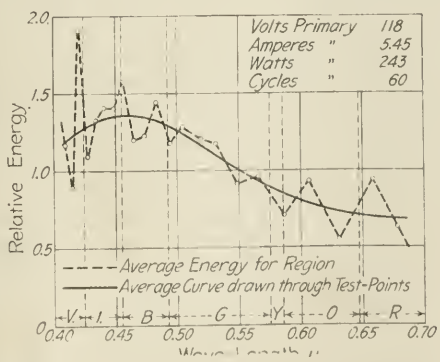
The application of this lamp was also illustrated by showing the difference in the color value of objects such as dress goods, silks, meat and flowers when illuminated first solely by the light of the standard tungsten lamp and then solely by the light of the Moore daylight tube lamp. In the course of his paper Mr. Moore called attention to the possibilities of the development of gaseous conductor lighting and the limitations of solid conductor lighting.

Elaborate spectrophotometric investigations have been made to show that articles of various colors, when viewed solely by the light of the new tube lamp, have exactly the same shades of color which they display when viewed by the light from a clear sky. Dyers and other color experts thoroughly agree that the standard light which they wish for color judging is that which enters a window from a clear north sky at an angle of about 45 deg., and preferably about mid-afternoon with a clear sun shining in the south.

There is reproduced in Fig. 1 the spectrophotometric curve of the CO_2 spectrum, which consists of a broken line with many jagged peaks, but an average of these peaks results in a smooth curve which gives a correct idea of the effective color characteristics so that it should be used for comparison with other line and continuous spectra. The effect of the banded character of the CO_2 spectrum, the tabulation of which consists of a broken line, was thoroughly investigated to determine its relation to the color-matching properties of the lamp.

The following samples of colored silk taken from the National Color Card of America were selected to represent the various parts of the spectrum and were spectrophotometrically tested to determine what the actual color composition was: violet, national blue, Yale blue, emerald, lemon, orange and scarlet.

The result of each of these tests was carefully plotted in the form of a curve, and a review of the data obtained in connection with these reflection curves showed that the irregularities in the CO_2 spectrum were absolutely without visible effect, and that they deviated only very slightly from north-sky values, to which they were compared. But it may be pointed out that if these north-sky values had all been taken at an angle of about 45 deg. there would have been no detectable variation, and that therefore the color-matching values of the CO_2 spectrum were all that could be desired.



CURVE SHOWING DISTRIBUTION OF ENERGY IN SPECTRUM OF CARBON-DIOXIDE TUBE LAMP

The straight-tube lamp is contained in an elongated sheet-metal case, which, however, is provided with a screw base similar to that used on the larger sizes of incandescent lamps. Instead of the lamp being fed CO_2 gas by means of an auto-magnetic feed valve, the gas is generated automatically within the tube itself. Near each electrode is placed a small bulb about an inch long, containing calcium carbonate, from which emanates the carbon-dioxide CO_2 when the resistance wires embedded in it become heated to the proper degree by reason of their being connected in shunt to the gas column. The gas column measures $\frac{7}{8}$ in. in diameter and 1 ft. in length, and appears as a solid bar of light of intense whiteness.

The foot-candles available near the tube total more than 200, making this apparatus suitable for the very closest color discriminations. The degree of vacuum is automatically held within 0.001 mm. of mercury column, and the apparatus will stand wide line-voltage fluctuations without becoming disarranged in any way.

This new lamp is suitable for making absolutely correct color determinations, and while it is applicable to a very wide field, it is particularly useful in enabling the dye shops of the great textile industry to run night shifts.

Since light is the source of all color, it has been proposed that this new lamp receive official recognition as a color unit from the International Conference on Electrical Units and Standards.

A NEW ARC LAMP WITH UNCONSUMED ELECTRODES

The last paper of the session was presented by Mr. **W. A. Darrah,** of the Westinghouse Company, on "The Electric Arc in Vapors and Gases at Reduced Pressures." The idea of the lamp seems fundamentally new as it is a flame arc lamp between tungsten electrodes which are not consumed. The light-giving qualities are obtained from special vapors introduced into the lamp. The paper was illustrated by lantern slides and experimental demonstrations, and was discussed by Dr. Moore and Mr. Mott. Mr. Darrah's paper is printed almost in full elsewhere in this issue.

Co-operation Between University and Industry

Meeting of New York Section of American Chemical Society

The first of a series of meetings to be held by the New York Section of the American Chemical Society for the discussion of the problem of co-operation between university and industry was held in Rumford Hall, Chemists' Club, Friday evening, Nov. 12. The attendance was very good and the hall was well filled.

After a short business meeting Dr. **T. B. Wagner,** chairman of the New York Section, said in his introductory remarks that research has not been developed in this country to the same extent as teaching. Even though many of our large establishments maintain finely equipped research laboratories we must look to the university for the training of the young man in research. Further activity in this work on the part of the universities is much needed. The far-reaching potential influence of university on chemical industry was forcibly brought to his attention when some years ago he visited his old teacher Emil Fischer and upon being shown into his study, he found the professor discussing an important industrial problem with the director of one of Germany's largest chemical concerns.

The speakers of the evening, President Butler and Professors Whitaker, Gies and Lucke, all of Columbia University, told of the work done there to aid the industries and of the further work which could be done. Their remarks were not intended, however, to apply only to Columbia but to every university.

President **Nicolas Murray Butler** of Columbia University, recalled with pleasure the chemical lectures of Professor Chandler he attended thirty-five years ago. He hesitated, however, to dwell upon the chemistry he learned in those early days fearing that the audience might regard it as archeology rather than chemistry. Chemistry has undergone many great changes in the last thirty-five years and the present European war has brought to the attention of the world the various stages of development in the different countries. In recent years we have heard much of the development and conservation of our natural resources, but not until this country felt the shock of the European war did it begin to realize the importance of organizing its forces, scientific and natural, for the strength of the nation.

Dr. Butler said great harm had been done in this country through the misuse of the word university. Any three men could get together in most States, except New York and Pennsylvania, he said, and form a university, so that the name has not had the proper significance to the general public and its aims and functions were little understood, consequently co-operation between the university and industry was not to be expected. But we are now beginning to see that a university is not only a place where persons are taught, but it is a public service institution. In the secondary schools and colleges knowledge is imparted to the young men, but in the university school emphasis is laid upon the extension and application of knowledge and upon the service of the public. A real university must be inspired and directed by the spirit of investigation and research.

Dr. Butler emphasized the performing of practical research. "Why do things for exercise in a university when there are so many practical questions waiting to be taken up." In this connection Dr. Butler told a story of a farmer digging a hole in front of his house and filling it up again for exercise while hiring a man to dig a trench for him. The university wants to keep down to a minimum the contrast between the academic and the practical. The university needs contact with and the co-operation of organized bodies of practical men, and these men should familiarize themselves with the university laboratories.

In America there is already more co-operation between the university and the industry than in England. At the School of Architecture at Columbia there is a visitors' committee of nine. Three of the large architectural societies of this country have each appointed three members to serve on this committee. It is the duty of this committee to make periodical visits to the university, to investigate the methods of teaching and to offer such improvements as they consider advisable. A similar committee would be of great service to the School of Chemistry and thereby further the co-operation of the school with the factory. The universities are ready and willing to welcome committees of this kind.

Prof. **M. C. Whitaker** took for his subject the work of Columbia in helping the chemical industries. Chemistry is very closely related to industrial development and the function of training men is one of the most important. The training which a man receives in order to eventually become a works manager, or to hold other responsible managerial positions may be divided into two parts, the portion done by the school and the portion done by the industry. The school gives the fundamentals and furnishes the student with a working basis. The industry is then responsible for allowing the man to gain the essential experience.

Professor Whitaker said the school is not able to make the rigid examination and inspection of its raw material as a manufacturer does in producing a manufactured product. The people of the industry should bear in mind that the university has no control over the "raw material" or student quality and should overlook a pardonable pride of the university whenever from rather crude material it turns out a "work of art." For this reason the yield cannot be 100 per cent from the combined training of school and industry. The industries often fail to appreciate this and expect too much. On the other hand they often fail to give the man the necessary opportunities to develop.

Industrial research has often been badly handicapped on account of unsympathetic surroundings of many of the factory laboratories. The young chemist is continually reminded of the importance of "production" and "profit" so that sooner or later he leaves his research and joins the factory force and his only chemical activity consists in the analysis of the shipments of coal.

The most important function of the educational institution is the opportunity for research. While it is true that some of our large companies have finely equipped and excellently conducted research laboratories, free from the hampering influence of the commercial production department, yet these involve a great expense and are not available to the average company. The university is the best place for research for most concerns. Professor Whitaker gave a brief outline of the course of chemical engineering at Columbia. All university research is industrial research. As regards pure research, the chief charm of it lies in its vagueness. The European war has forced us to realize that it is high time "to cash in" our scientific knowledge and make it immediately available.

Prof. **W. J. Gies,** in speaking for the department of biological chemistry said he represented the side on which both the industry and the university might help the investigator. He reviewed the work of Pasteur on the tartrates, fermentation and the French silk industry, and showed how Pasteur's researches had been of great practical application and had been suggested and helped along by his contact with the industries. He said the biological department of Columbia had been hampered in helping the industries because it had to uphold the honesty of its work. He said it was the exception rather than the rule to be asked to do honest work for some industrials. The biological department has been approached with all sorts of crooked food and medicine schemes but has had to refuse all except where a direct public benefit was to be gained. Professor Gies emphasized that it was "up to the industry. Gentlemen of the industry, it is your move."

Prof. **Charles E. Lucke,** in speaking for the mechanical engineering department said that mechanical engineering must necessarily follow chemistry and furnish the means for transferring its principles into practice. Taking the chemical industry as a whole, the equipment is largely made up of standard machinery for the different operations, such as filter presses, centrifuges, crushers, etc. The improvements arising from research in the chemical industry are not, however, all chemical. The indirect aids may sometimes be forgotten. So many contributions of the universities are indirect that they are unfamiliar to the industries and hence do not receive the proper application. New apparatus and equipment is the most important indirect contribution. The next important is fault discovery. This is a duty which

can be performed by the university investigation.

In taking up new ideas it is all important to have an experimental construction to obtain accurate data. Here is where a great barrier has arisen. Many splendid ideas have never had the necessary experimental trials for accurately deciding upon their value, and on the other hand many poor ideas have been tried and when they failed the commercial men have become discouraged and looked with disfavor upon new ideas and tests. After an experimental trial has been brought to a successful termination the final stage is the design of the apparatus. Here the university laboratory can play no part. Any correct analysis of the relations between university and industry will show that the industry is receiving both direct and indirect contributions limited only by financial support.

The chairman, Dr. Wagner, announced that the discussion would be postponed to a later meeting inasmuch as several meetings are to take up the same subject.

American Institute of Mining Engineers

New York Section

The New York Section of the American Institute of Mining Engineers, of which Mr. David H. Browne is the chairman, is arranging an interesting program for this season. The meetings will be informal dinner-meetings, affording a means of friendly intercourse, and the general tendency was well indicated by the first meeting held on Oct. 28, devoted to a discussion of the New York Subways, when the presentation of this subject by the engineers of the Subway Commission was appreciated by a large audience. The endeavor is to handle matters of general and timely interest rather than technical subjects which interest only a few. Among the subjects which will be taken up in later meetings are "The Engineer in Modern Warfare" and "The Problems of the Naval Advisory Board."

Coal and Iron in Nova Scotia and Newfoundland

Meeting of the Mining and Metallurgical Society

On Thursday, Nov. 18, a meeting of the Mining and Metallurgical Society was held at the Machinery Club, New York City. After an informal dinner, the address of the evening was made by Major C. L. CANTLEY of New Glasgow, Nova Scotia, assistant to Mr. Thomas Cantley, the president and general manager of the Nova Scotia Steel & Coal Company, concerning the coal mines of Nova Scotia and the ore mines of Newfoundland.

Major Cantley has had an acquaintance with these properties from boyhood up, not only from an office point of view, but has spent several years at and in the mines themselves, participating in the very extensive and thorough geological studies which resulted in proving definitely the extent of the ore mines, whose outcrops occur on the land, but the vast proportion of which extends out under the ocean.

Major Cantley first described, briefly, the coal mines of the Pictou region, which are not particularly large and do not differ in important parts from other coal mines, and then passed to a description of the vast coal beds at the northeast end of Cape Breton Island. These outcrop on the land, but dip at a low and uniform angle out under the ocean, the farthest commercial outcrop being only about a mile and a half back from the shore. The Dominion Coal Company and the Nova Scotia Steel & Coal Company now control practically all the important part of this field. They have each patented submarine areas many square miles in extent out under the ocean off Sydney Harbor. The commercial development of these mines is much older than is generally realized in the United States, there having been coal mines of commercial importance in the district for over a century. By far the greater proportion of the coal mined in this field is used for bunker and commercial purposes, but the slack which results, is washed to reduce its ash and sulphur and then coked. When properly handled, the coal from some of the seams makes a good metallurgical coke.

The outcrops of the ore body are quite close to the shore of Bell Isle, a small island in Conception Bay on the extreme southeast corner of Newfoundland. The ore beds of commercial size are three in number and exceedingly uniform; even more uniform than those of the Birmingham district, as well as much richer, the ore running regularly from 50 per cent to 53 per cent in iron. These ore beds are separated and overlaid by strata of sandstone and shale, the sandstone forming the roof and greatly facilitating mining, since absolutely no timber is required. The ore beds dip out to sea at a very uniform rate of about 10 deg. and the mines are now being worked a mile and a half or two miles out under the sea.

Very careful geological examinations indicate that the quantity of ore commercially available is not less than half a billion tons and may be as high as three billion tons, constituting one of the largest of the world's ore reserves. This ore is transported to Sydney and used in the blast furnaces, of which there are nine of moderate size and good modern construction on Sydney Harbor, owned by the two companies above mentioned. The output of these furnaces is converted to steel in basic open-hearth furnaces at the two plants.

The Dominion company finishes its steel at the Sydney plant, but the Nova Scotia Steel & Coal Company ships ingots from its plant to New Glasgow where the parent works are. These include blooming mill, finishing mills and very extensive hydraulic forging plant, where forgings of very large size are produced, as well as railroad axles and the like. There are also shops for converting steel into track material, concrete bars and the like.

Just recently, a magnificent car plant has been completed and is now turning out a large number of steel and steel-and-wood cars for foreign governments.

Colonel Cantley's talk was informal and was supplemented by the replies to a great number of questions which were asked by the members.

After this technical discussion was concluded, Colonel Cantley acceded to the request of the members to tell them something of his experience in the trenches, he having been in Flanders until the late summer, when he was detailed home to assist in the manufacture of war munitions. His talk on this subject was of the keenest interest to all and a hearty vote of thanks was extended to the speaker for the pleasure and entertainment he had afforded the meeting.

The Western Metallurgical Field

Canadian Bounty on Zinc

Announcement was recently made in press dispatches emanating from Ottawa that the Canadian Government had offered a limited bounty on zinc produced in the Dominion from Canadian ores. The object of the bounty is to encourage the immediate refining of zinc within the country, and to protect producers from possible decline in the price of zinc between the end of the European war and July 31, 1917. The total amount of bounty to be paid is not to exceed $400,000, and individual payments will be made on a sliding scale not exceeding 2 cents per pound of zinc containing not more than 2 per cent impurities, when the standard

London price for zinc falls below £33 per ton. The bounty is not payable on zinc produced before the expiration of the war or after July 31, 1915, or on zinc that is sold to the Government at a price of 8 cents or more per pound.

Zinc in British Columbia

The value of the zinc deposits of British Columbia and the metallurgical problem presented in their profitable treatment have been fully recognized for many years, at least since 1906, when Messrs. Ingalls, Argall and Gardé made an elaborate report on their investigations for the Canadian Government. Zinc in British Columbia occurs associated with lead, and has been an impediment to the reduction of the ores. Concentration has accounted for a considerable production, however, which has been shipped to the United States for smelting. Electric smelting has been tried, a plant having been erected at Frank, Alberta, in 1904, and at Nelson, B. C., in 1908. Further experiments were made at McGill University in 1910 and again at Nelson in 1913, but none was commercially successful, mainly due to difficulties in condensation of the zinc vapor.

At the present time the problem is being attacked along different lines, looking toward a hydrometallurgical treatment of the ores and electrolytic reduction of zinc. Different processes are being tested, but in general they involve the roasting of the zinc-lead-silver ores, extraction of the zinc by leaching, electrolysis of the lixivium and smelting of the lead-silver residue. At Trail, B. C., the Consolidated Mining & Smelting Co. is using sulphuric acid as the solvent and electrolyzing zinc sulphate solution. The Weedon Mining Co. is using the Watts process in a new plant at Welland, Ont., and the Standard Silver Lead Mining Co. has adopted the French process at its works at Silverton, B. C.

The French Process for Electrolytic Zinc

The process of A. Gordon French was recently described in the *Bulletin* of the Canadian Mining Institute, in an excerpt from an article contributed by a metallurgical engineer to the Nelson *Daily News*. "The method consists in the use of a solution of bisulphate of soda, which is a cheap waste product, and a small quantity of manganese—an ingredient which occurs with most zinc ores. Bisulphate of soda dissolves the zinc from the roasted ore almost instantaneously. Along with the manganese in solution it completely prevents the anodes from being affected and after years of constant use they are as good to-day as at the beginning. This solution also has very little resistance to the passage of the electric current in the electrolytic vats and the consumption of current is thus lowered. It has also the peculiarity of throwing out of solution practically all the impurities which usually contaminate the zinc. Early in 1912 the Consolidated Mining & Smelting Company of Canada acquired the sole rights for the use of this process in Canada. It was only toward the end of last year that they had partially erected a plant of somewhat large dimensions, and after they had produced a few tons of zinc the contract between French's company and the Consolidated was canceled.

"A demonstrating plant was then erected at Silverton, Slocan Lake, by the Standard Silver-Lead Mining Co., on a large enough scale to thoroughly prove that the process would work equally well on a very large scale. It comprised two completely equipped dissolving vats, each capable of dealing wth 2500 lb. of liquor at a time and about 1000 lb. of ore. The zinc-depleted liquor containing bisulphate of soda from the electrolytic vat is pumped into the upper of these two vats. There is then added 700 to 1000 lb. of roasted ore from which the zinc has been partially extracted in a previous operation. In about an hour solution of the zinc is finished and when the liquor has settled for a short time it is allowed to run down into the second dissolver, placed at a lower level. The sludge remaining in the bottom of the dissolver is then pumped through a filter press to remove the water and the residue contains all the silver and lead. As the sulphur to the extent of more than 20 per cent has been driven off in the roasting operation and zinc to the amount of about 40 per cent has been extracted, the residue of the ore, of which a large quantity was treated, only weighed about 45 per cent of the original ore used. As it contained all the silver and lead originally in the roasted ore, the percentage of these metals was more than doubled. For instance, the ore treated had 31 per cent zinc, 3.5 per cent lead, and 32 oz. silver per ton. The zinc depleted residue contained 76 oz. silver per ton, and 8.7 per cent lead, and 92 per cent of the zinc had been taken out, i. e., 2.7 per cent of the zinc counted on the original ore used was left in the residue. This residue is now ready for smelting or other treatment for the recovery of its lead and silver in the usual way.

"To the liquor which has been run down into the second dissolver, a quantity of roasted ore is again add to neutralize the bisulphate of soda. As soon as this has taken place the liquid settles very rapidly to a clear solution, which is pumped through a clarifying filter press, and is then ready to have its zinc deposited in the electrolytic vats. At the Standard Co.'s plant only one electrolytic vat was used, as the dynamo power at disposal there was limited. Nine anodes were used and eight cathodes of the largest size each with an area of 8 sq. ft. What can be done with one vat can be done with any number on a large scale, a reduplication of vats of the same sizes being all that is necessary. The plant was well designed and erected and the results of running a large quantity of ore gave a remarkable good current consumption. Although 4000 kw.-hr. were allowed in costing for the deposition of 1 ton of zinc, only 3000 kw. were actually required, the lowest reading over a period of 48 hr. having been 2680 kw.-hr. On another occasion a 70-hr. run gave 2860 kw.-hr. As the zinc is deposited from solution in the electrolytic vat, the bisulphate of soda with which it was combined is regenerated and is used again in the next dissolving. The working costs vary with the ore, but they are now well defined and it is possible to give with some accuracy an idea of the profit which the district will derive from the working of this process near Nelson.

"The plant is expensive, but very much less than that required for a zinc smeltery of similar capacity. To deal with all the ores in this district some millions of dollars would be required for the plant alone. Ores of almost any grade above 10 per cent zinc can be treated equally well, but naturally the cost of treatment for an ore with a larger zinc content is less. As an example, an ore containing 24 per cent zinc, 24 per cent lead and 20 oz. silver per ton may be taken. Almost any of the mines can supply this or a better grade by picking or slight concentration without much loss of value. Taking zinc at 5 cents a pound, the lowest price at which it is possible for an ordinary zinc smeltery to work, and allowing freight on metallic zinc as far as Europe or China; lead at £20 per ton (London), and silver at 50 cents per ounce, and deducting ample costs for treatment, depreciation, management and royalty, the miner would receive for his ore about $18.50 net per ton. It is only necessary to deduct cost of mining, picking the ore and freight to determine the net amount per ton the miner would receive for his ore, i. e., in the

neighborhood of $15 per ton. For a supply of 500 tons of ore per day the net benefit to the miners would amount to upward of $2,500,000 per annum."

New Chloridizing Mill for Tintic District, Utah

By early spring next year it is expected that a new mill will be operating in the Tintic district, Utah, using the process of chloridizing, roasting and leaching that has been described on several occasions in this journal. The new mill is being built by a company representing a consolidation of interests formerly operating separately at Park City and Silver City, Utah. The Mines Operating Co. was treating ore from the Ontario mine at Park City, using the Holt-Dern roaster, while the Knight-Christensen Metallurgical Co. built a mill at Silver City and used a Christensen roaster. The Mines Operating Co. found it inadvisable to continue operations under the conditions existing at Park City, and the Knight-Christensen company lost its Silver City mill by fire. As a result of a combination of circumstances, a consolidation of interests has been effected, and the Tintic Milling Co. has been organized to construct a new mill on the site of the old Knight smelter at Silver City. The officers of the new concern are: Jesse Knight, president; W. Lester Magnum, secretary; George H. Dern, vice-president and general manager; Theo. P. Holt, superintendent. The new mill will contain three Holt-Dern and one Christensen roasters, and as the two will be operated under identical conditions, an excellent opportunity will be afforded to compare their relative merits. The Tintic district affords an unlimited quantity of ore suitable to the process, and the new venture is expected to prove a boon to the district and yield a satisfactory profit to its promoters.

The Iron and Steel Market

The runaway in steel prices has proceeded farther and has perhaps reached the stage at which buying for ordinary purchases ceases, for the time being at least. Buyers, as a rule, are covered for many months ahead and chiefly, of course, at prices much below the advanced level now ruling. New wants arise, but there will naturally be hesitation about filling them. Thus the Pennsylvania Railroad has decided not to buy the 11,000 freight cars against which it recently issued inquiries, announcing that bids made are too high and deliveries proposed too slow. In the case of ship material buyers might not hesitate to pay prices asked, or even higher prices, but there is not much ship material coming up now, the yards being already well filled with business.

A decided increase is noted in inquiry for structural material, suggesting that much more building is planned for next year than has occurred in the past two years, but it remains to be seen whether a large volume of business can be put through at present prices.

Specifications on steel contracts continue to come in at a great rate and the mills are falling still farther behind in deliveries. Some of these current contracts for bars, plates and shapes are at 1.15 cent and 1.20 cent and specifications now filed against them will not be filled in many instances in less than from two to four months, so that a very wide range exists in invoice prices, since the current quotation on bars, plates and shapes for shipment at mill convenience is 1.70 cent, and small lots of bars and plates are bringing as high as 2.00 cent.

From some quarters come urgent requests to the mills for quicker deliveries, but there is no doubt that many buyers are comfortably fixed as to deliveries, if, indeed, they are not receiving material faster than they need it. Naturally buyers take all the material their low-priced contracts permit, even if this causes the accumulation of considerable stocks. A condition that always obtains after a material rise in steel prices is that of some buyers, who were fortunate in placing large contracts at low prices, accumulating stocks of material or piling up specifications at the mills, and the existence of such a condition makes it difficult to judge the future, for one does not know whether buyers would be as enthusiastic about securing deliveries if they saw the market become stationary or start declining. Their physical needs might be the same, but their interpretation of them would be different.

In most finished lines the mills have business on books insuring operation at full capacity to about the middle of next year, and the chief exceptions to this condition are lines that do not customarily book business so far ahead. As a rule, new contracts could be taken only for third quarter of next year, and the mills do not wish to look so far ahead.

The production of steel is not increasing further, as the limit of capacity had already been reached. It seems safe to estimate that ingots are being produced at the rate of more than 40,000,000 tons a year.

Pig Iron

Prices have been advancing sharply in the past fortnight in nearly all markets. The advance is due much less to heavy market demand than it is to the productive ranks being well obligated to buyers already. Until but a few weeks ago advances in pig iron were either forestalled, or were greatly restricted in amount by the blowing in of idle furnaces. With considerable suddenness the limit is being reached, there being few idle merchant furnaces remaining, and some of those cannot blow in because they are not provided with ore, and nothing can be done with them until ore comes down the lakes next season. There has been, on the whole, a slight improvement in pig iron demand from foundries, but the foundries are still far from taking the tonnages they require in normally prosperous times. The steel works are not heavy buyers, but such purchases as are made count strongly in the market for the reason that the steel works that normally buy iron had already bought for forward delivery and present purchases are of additional lots. The furnaces claim to be well sold up, and effect price advances without any difficulty, but experience shows that in conditions like those of the present furnaces may have the appearance of being more sold up than is the case. If an accident occurs in the market it always turns out that there was more unsold iron than was estimated. As the market is trending now there will be sharper advances in the next two months than have occurred lately, even though during November the average price of all important descriptions of pig iron has advanced fully $1.50. The more important advances in the past fortnight are 50 cents in Bessemer and basic $1 in found iron at valley furnaces, $1 in the Buffalo market and 50 cents at Philadelphia and Cleveland. We quote: No. 2 foundry iron, delivered Philadelphia, $17.75 to $18.25; f.o.b. furnace, Buffalo, $17.50 to $18; delivered Cleveland, $17.30; f.o.b. furnace, Chicago, $17.50 to $18; f.o.b. Birmingham, $13.50 to $14; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $17.50 to $18.00; basic, $16.50 to $17; No. 2 foundry and malleable, $17; gray forge, $16.50.

Statistics returned from upper lake docks indicate that the movement of iron ore out of the Lake Superior region this season, including all-rail traffic, will total about 47,000,0000 tons, or within 3,000,000 tons of the record, made in 1913. Ore prices for next season are expected to be announced shortly, at an advance of 75 cents to $1 a ton over the schedule for the season just

closing, a schedule identical with that of 1912 and 1914, prices in these three years having been the lowest since 1904.

Steel

Transactions in billets and sheet bars have been limited almost entirely to sales to regular consumers, who depend upon some particular source of supply, and odd lots disposed of by brokers. There is no regular market for Bessemer steel, while there is practically no market at all for open-hearth. Prices nominally representing the market so far as there can be said to be one, are approximately as follows: Bessemer billets, $28; sheet bars, $28 to $28.50; open-hearth billets, $29 to $30; sheet bars, $29.50 to $30, f.o.b. maker's mill, Pittsburgh or Youngstown. Forging billets are $48 to $50 and wire rods about $35.

Finished Steel

Prices have been advancing sharply almost all along the line. Nov. 18 the Carnegie Steel Company advanced bars, plates and shapes $2 a ton, to 1.70 cent, this price instantly becoming the minimum of the market. Premiums are the rule in bars and plates for early deliveries. Prices quoted are f.o.b. Pittsburgh unless otherwise noted, and are for ordinary deliveries:

Rails, standard sections, 1.25 cent for Bessemer, 1.34 cent for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.70 cent.

Shapes, 1.70 cent.

Steel bars and bands, 1.70 cent, base; steel hoops, 1.75 cent, base.

Iron bars, 1.759 cent to 1.809 cent, Philadelphia; 1.60 cent, Chicago; 1.60 cent, Pittsburgh.

Plain wire, 1.75 cent; wire nails, $1.90 per keg, base; painted barb wire, 2.05 cent; galvanized barb wire, 2.75 cent.

Sheets, blue annealed, 2.00 cent to 2.10 cent; black, 2.40 cent to 2.50 cent; galvanized, 4.50 cent to 5.25 cent; painted corrugated, 2.20 cent to 2.30 cent; galvanized corrugated, 4.55 cent to 5.30 cent.

Tin plate, $3.60 for 100-pound cokes.

Steel pipe, ¾ to 3-in., black, 78 per cent off list; galvanized, 63½ per cent off list.

Boiler tubes (less than carloads) 3½ to 4½ in., 69 per cent off list.

Structural rivets, 2.40 cent; boiler rivets, 2.50 cent.

Non-Ferrous Metal Market

The situation in this market for the two weeks ending Nov. 23 has been one of advancing tendency in all directions. These advances for the most part have been legitimate, and due to increased demand. There is great difficulty in obtaining spot deliveries and futures are well sold up.

Copper.—On Nov. 8 electrolytic was quoted at 18@18¼ cents. This price remained fairly steady for a week despite the closing of the Nichols Refinery at Laurel Hill, L. I., by strike on Nov. 10, which removed more than a million pounds from the daily production. On Nov. 12 the price had risen to 18½ cents for electrolytic, and by the 17th the price was 19 cents. Consumers may have been frightened into buying by the advancing market. By Nov. 20 the price had reached 19½ cents, and on the 22nd the much talked of 20-cent copper was realized. Exports up to Nov. 23 were 16,570 tons (compiled by N. Y. Metal Exchange). The strike at Laurel Hill was settled Nov. 16.

Tin.—The condition in the tin market has been one of extreme irregularity. The limited supply available and the uncertain reports have upset the market. Demand has not been normal, otherwise an acute situation might have developed. On Nov. 10 the spot market was 37 cents, when the report of the closing of the Suez Canal drove the price up until 44½ cents had been reached on Nov. 15. The market then reacted when it was found that this report was not true, and on the 22nd the market was weak and dull, with spot at 39 cents. Total arrivals up to Nov. 23, 1100 tons.

Lead.—The lead market was strong, with two advances recorded by the Trust between Nov. 8 and 23. On Nov. 10 the price was advanced 0.15 to 5.15 and on Nov. 15 it was advanced 0.10 to 5.25. This price has held steady. The market is pretty well in the hands of the Trust, and there was little inquiry in the outside market. There has been an absence of speculation.

Spelter.—The demand for this metal has been extremely good, and an advance of substantially 3 cents was recorded. On Nov. 8 spot was quoted at 15.20 New York. During the next two weeks heavy buying and a flood of inquiry sent prices soaring, and on Nov. 22 prime virgin spelter was quoted at 18.75@19.25 on the N. Y. Metal Exchange.

Other Metals.—Aluminium has held firm at approximately 56@59. On Nov. 18 sales of 200 tons were reported at close to 58, which staggered the market momentarily, but the price has, however, held firm. Antimony has advanced about 3 cents per pound on heavy demand, and on Nov. 22 was quoted at 38@39. Silver rose from 50⅛ on Nov. 8 to 52⅛ on Nov. 22. Platinum, on account of the French embargo, is now quoted $68 for soft. Quicksilver rose $5, to $105 per flask.

The Roessler & Hasslacher Chemical Co., New York, was awarded a gold medal at the Panama-Pacific Exposition for its exhibit of cyanides.

Iron in Utah—Articles of incorporation have been filed by the Utah Iron & Steel Co., capitalized at $300,000. This is the first step in developing the iron fields of Utah, the company having a new plant in operation at Midvale which may be enlarged. The headquarters will be at Salt Lake City.

Antimony mining in Japan has had a great impetus as a result of the war. Prior to 1914 the mining of this metal in Japan was neglected on account of the cheapness of imported Chinese sulphide of antimony, but at the present time the production is about 50 tons a month. Consumption in Japan is roughly about 450 tons a month.

Mineral Resources of Quebec—According to a recent consular report, by far the greater part of the Province of Quebec is as yet unprospected. The mineral products produced are aluminium, asbestos, antimony, arsenic, chromite, copper, feldspar, gold, graphite, iron, lead, zinc, magnesite, mica, molybdenum, phosphate and ocher. An important amendment to the mining laws of this province was passed in 1914. Lands containing combustible natural gas, mineral oil, or naphtha may now be staked, either ordinary or for a long term, upon conditions which are favorable for exploration.

The famous "silver sidewalk," considered to be the largest slab of native silver in the world, has been removed from the La Rose property at Cobalt, Canada, and placed in the museum in Toronto. The preservation of this remarkable specimen of silver ore was undertaken by the provincial government, and the greatest care was exercised in its removal. It is reported that drill holes surrounding the mass were filled with unslaked lime, after which water was added and the holes plugged. The pressure exerted by the slaking of the lime dislodged the slab with the least possibility of fracture.

Alumina in Steel

BY GEORGE F. COMSTOCK

One reason for the value of the microscope in the examination of steel is its ability to give evidence as to the cleanness of the metal, or as to the number and character of the non-metallic inclusions embedded in it. By preparing a surface with a sufficiently perfect polish, not only the number of inclusions per given area can be ascertained, but their shape, color and arrangement through the metal can also be plainly seen if lenses of good quality and fairly high magnifying power are used. After examination of many samples of steel with especial regard to the non-metallic inclusions, experience is acquired by which these inclusions may be classified into several different types based on their appearance in a well-polished unetched steel surface.

The sulphides are the most common inclusions in steel, and their appearance is well known to all metallographers. Inclusions of this type used to be known as "manganese sulphide," but investigations made in recent years have shown that iron sulphide also enters into their composition to a considerable and variable extent. Next to the sulphides, the most common inclusions are the silicates, or true slag inclusions. These are always darker than the sulphides and usually of more irregular form. To some writers, all inclusions except sulphides are "slag," and others do not even make this exception, calling everything "slag" in a polished section that is not metal. From evidence obtained recently in these laboratories, however, it has seemed justifiable to differentiate between slag or silicate inclusions and those consisting wholly or chiefly of titanium nitride, or of alumina, respectively. The titanium nitride inclusions were described in the METALLURGICAL AND CHEMICAL ENGINEERING for September, 1914, Vol. XII, page 577, and are easily distinguished from all other inclusions in steel by their pink color. In this report is presented the evidence on which the identification of alumina in steel has been made.

A few years ago an ingot of good steel was treated, in the mold, with a large excess of aluminium, and the bars forged from this ingot were very seamy. Photomicrograph Fig. 1 shows the appearance of the inclusions in this steel, which must evidently be alumina, since nothing but this was added to the molten metal.

These inclusions are in the form of small rounded spots, arranged close together in an elongated streak. They are of a very dark bluish-gray color, when examined with the white light of an electric arc, appearing black unless highly magnified, and it is practically impossible to polish them without forming little pits around each inclusion. If the polishing is done very carefully these pits may be kept very small; but with certain methods of polishing the pits are made so large that the original inclusions cannot be seen at all. Titanium nitride inclusions will form pits in the same way if poorly polished. If the specimen is not rotated constantly during the final polishing, the pits take the form of short scratches, and each inclusion will have a little tail, like a comet.

It will be noticed in photomicrograph* Fig. 1 that although this shows a longitudinal view of a bar, the individual inclusions have not been elongated by the forging at all, but merely the group as a whole has been drawn out into a streak. Compare this with Fig. 2, which shows some silicates in the web of a rail, and a great difference will be apparent, for the silicates have been elongated even by the crosswise pressure of the rolls forming the web, while the drawing effect of the forging did not elongate the alumina particles even in the same direction that the bar was drawn out.

The difference between inclusions of alumina and ordinary slag or silicates in steel may then be summarized as follows:

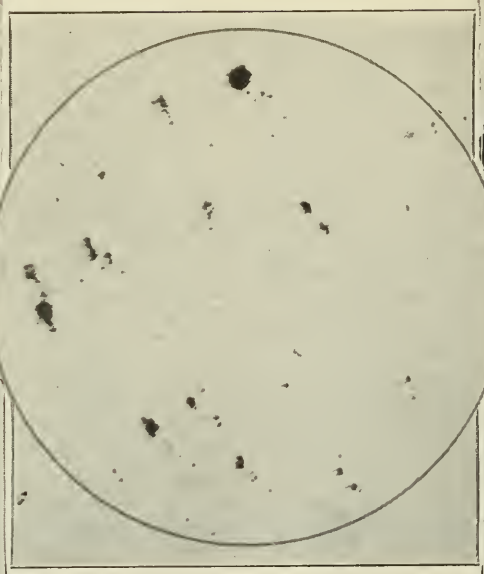
*All photomicrographs show unetched sections.

NO. 1—INCLUSIONS OF ALUMINA IN SECTION PARALLEL TO DIRECTION OF FORGING OF STEEL TREATED WITH A LARGE EXCESS OF ALUMINIUM. THE FEW GRAY SPOTS ARE SULPHIDES. MAGNIFIED 200 DIAMETERS AND UNETCHED.

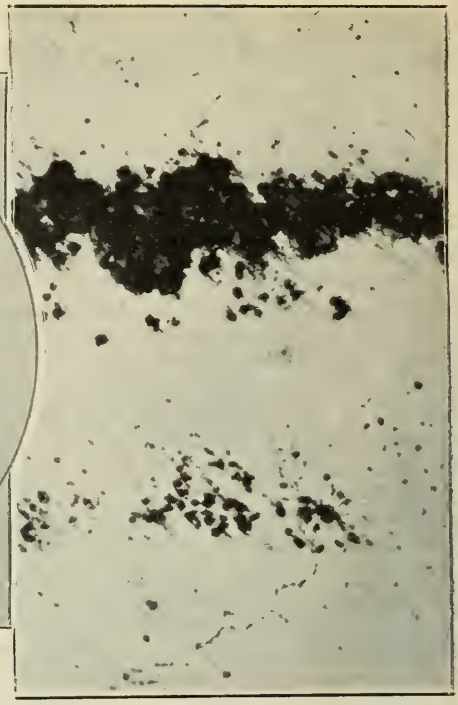
NO. 2—SILICATE OR SLAG INCLUSIONS (WITH A FEW GRAY SULPHIDES) IN THE CROSS SECTION OF THE WEB OF A RAIL. MAGNIFIED 200 DIAMETERS AND UNETCHED.

NO. 3—ALUMINA INCLUSIONS IN A SOFT STEEL INGOT IN WHICH MORE ALUMINA WAS FOUND BY CHEMICAL ANALYSIS THAN ALL OTHER OXIDES. MAGNIFIED 200 DIAMETERS AND UNETCHED.

NO. 4—SILICATE OR SLAG INCLUSIONS IN THE CROSS SECTION OF THE HEAD OF A RAIL. MAGNIFIED 200 DIAMETERS AND UNETCHED.



NO. 5—SECTION OF BROKEN SPLICE-BAR IN WHICH 0.019 PER CENT OF ALUMINA WAS FOUND BY CHEMICAL ANALYSIS. 200 DIAMETERS.



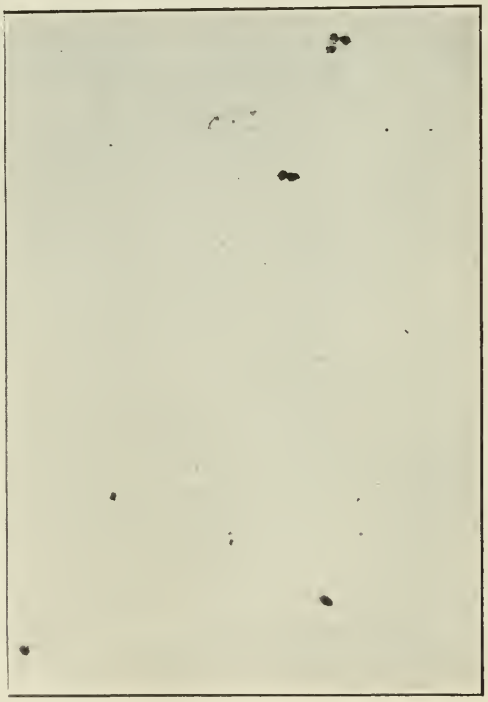
NO. 6—ALLOY, MADE IN SMALL ELECTRIC FURNACE, OF ALUMINO-THERMIC FERRO-TITANIUM WITH SWEDISH IRON. 400 DIAMETERS.

(1) Silicate inclusions will generally take a fairly smooth polish in a section prepared for microscopic examination, while alumina is very hard to polish without pitting.

(2) Silicate inclusions are always elongated in the direction of rolling or forging, while alumina particles are not (the *groups* of particles are, of course, elongated, but not the particles themselves).

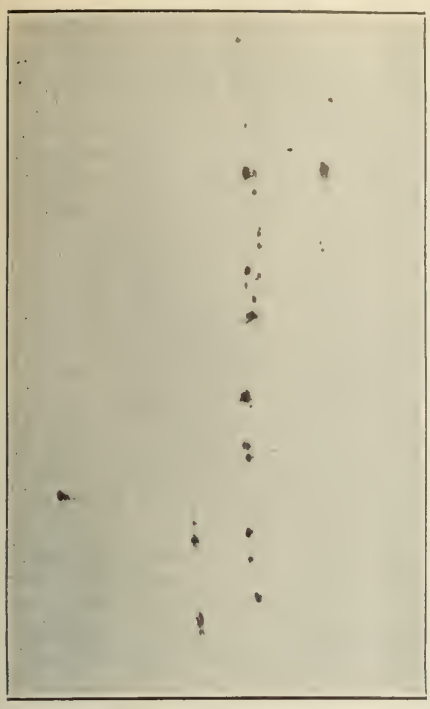
(3) Silicate inclusions are often found of quite large size (as well as very small), while particles of alumina are always small, and do not seem to coalesce into larger bodies even when closely grouped together.

NO. 7—GROUP OF SEGREGATED INCLUSIONS IN CROSS SECTION OF THE WEB OF A RAIL, IN WHICH 0.003 PER CENT OF ALUMINA WAS FOUND BY CHEMICAL ANALYSIS. MAGNIFIED 200 DIAMETERS.

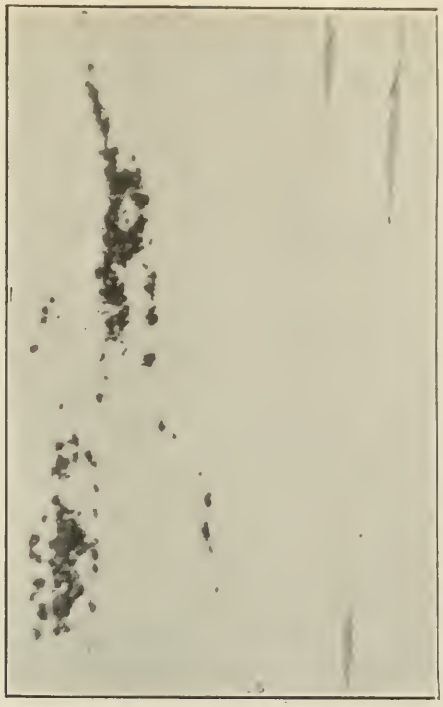


NO. 8—AVERAGE VIEW OF THE CROSS SECTION OF THE HEAD OF A RAIL IN WHICH 0.010 PER CENT OF ALUMINA WAS FOUND BY CHEMICAL ANALYSIS. MAGNIFIED 200 DIAMETERS.

NO. 9—STREAK OF ALUMINA INCLUSIONS BADLY POLISHED, SHOWING PITS AND SCRATCHES. MAGNIFIED 200 DIAMETERS AND UNETCHED, SHOWING "COMET TAILS" DUE TO POLISHING.



NO. 10—SAME STREAK SHOWN IN NO. 9 AFTER GRINDING AND MORE CAREFUL POLISHING. MAGNIFIED 200 DIAMETERS AND UNETCHED. THE ALUMINA INCLUSIONS SHOW NO "COMET TAILS" AS PITTING HAS BEEN AVOIDED.



NO. 11—LONGITUDINAL SECTION OF A STREAK THAT CAUSED THE TOP OF THE HEAD OF A RAIL TO SHELL OFF, SHOWING ALUMINA INCLUSIONS AT THE LEFT AND SULPHIDES AT THE RIGHT. MAGNIFIED 200 DIAMETERS AND UNETCHED.

NO. 12—TYPICAL LARGE SILICATE OR SLAG STREAK IN THE CROSS SECTION OF THE WEB OF A RAIL, SHOWING ALSO TWO PARTICLES OF ALUMINA AND SOME FINE GRAY SULPHIDES. MAGNIFIED 200 DIAMETERS AND UNETCHED.

These characteristics of the alumina inclusions agree with what is known of the properties of alumina. Its great hardness and brittleness would account for the pitting effect; its infusibility would account for the small size of the particles and the tendency not to coalesce; and both of these properties together would account for the particles not being elongated by forging or rolling of the steel in which they are embedded.

NO. 13—ALUMINA INCLUSIONS IN CLEAN RAIL STEEL TREATED WITH AN EXCESS OF ALUMINIUM. MAGNIFIED 200 DIAMETERS.

NO. 14—SLAG INCLUSIONS IN SIMILAR STEEL TREATED WITH OXIDE OF TITANIUM BEFORE CASTING. MAGNIFIED 200 DIAMETERS.

NO. 15—STEEL TREATED WITH OXIDE OF CHROMIUM, SHOWING END OF A BROAD STREAK, WITH TYPICAL SMALL PARTICLES EMBEDDED IN THE METAL. 200 DIAMETERS.

Inclusions having all the characteristics of those seen in steel known to contain alumina have been found in many samples of steel examined in the course of our work here, but it could not be stated positively that any of these were alumina until a method was found for determining this substance quantitatively by chemical analysis. Eventually such a method was found, not only in our laboratory, but also independently by Mr. F. O. Kichline, chemist at the Saucon plant, Bethlehem Steel Co. (published in the September, 1915, issue of the *Journal* of Industrial and Engineering Chemistry) and the results from it have been very interesting.

All samples in which more than the merest trace of alumina was found by analysis were seen to contain the typical inclusions as described above, and those in which alumina was not found by analysis did not contain these inclusions. Furthermore, those in which more alumina was found by analysis contained more of these inclusions than those in which only a very little was found.

NO. 16—STEEL TREATED WITH OXIDE OF NICKEL, SHOWING TYPICAL INCLUSIONS OF EITHER NICKEL OXIDE OR IRON OXIDE. MAGNIFIED 200 DIAMETERS.

These facts have been considered as a good confirmation of the theory that the typical small inclusions, as described above, found in so many commercial steels are chiefly, if not wholly, alumina. Of course, the purity of the alumina in these inclusions is not known, but even if it is fluxed with some impurity it would seem proper to call the inclusions "alumina" when it is known that their character is determined by the presence of this substance.

Photomicrograph Fig. 3 shows the inclusions in an ingot of soft steel in which chemical analysis showed the presence of a much larger amount of alumina than of all other insoluble oxides, thus proving the presence of a considerable quantity of free alumina.

Fig. 4 shows some ordinary slag inclusions in a cross-section of the head of a rail.

This photomicrograph and Figs. 2 and 12 are included to show the difference between silicates and alumina.

Fig. 5 shows a section of a splice-bar which broke in a railroad track and was found by analysis to contain 0.019 per cent of alumina.

Fig. 6 is an alloy made on a very small scale of Swedish iron and aluminothermic ferrotitanium, and shows alumina which was not present in the original iron.

Fig. 7 shows a spot where alumina particles are segregated in the web of a rail, in which 0.003 per cent was found, and Fig. 8 is an average view of the head of another rail containing 0.010 per cent of alumina. Fig. 8 shows the most common mode of occurrence of these particles, that is, scattered thinly through the metal. In Fig. 7 most of the specimen showed very few inclusions, but the small segregated streaks shown in the photomicrograph are more dangerous to the life of the rail than the larger total amount of alumina in Fig. 8, where it is arranged differently.

Figs. 9 and 10 are photomicrographs of the same streak, differently polished; the former shows the comet-tails mentioned above, while in the latter the pitting has been more successfully avoided.

Fig. 11 is a view of some streaks that caused the top of the head of a rail to shell off from the rest of the section. The form of the alumina is well contrasted with the sulphides and with the large slag inclusion in Fig. 12, which is a large but typical silicate streak in the web of another rail.

All these photomicrographs show open-hearth steel, except possibly Fig. 5, which may be Bessemer, and Fig. 6, which is an electric-furnace melt. All show unetched surfaces, and all except Fig. 6 were taken with a magnification of 200 diameters. Fig. 6 was magnified twice as much as the others.

As a final check on the accuracy of the assumption that all inclusions in steel, having exactly the same characteristics as those shown in photomicrograph Fig. 1, are alumina, several experimental melts were made of rail steel with the addition of various oxides. The steel used was seen by previous microscopic examination to be practically free from non-metallic inclusions except sulphides, and ten-pound ingots were cast from it each treated with one of the following oxides: alumina, titanium oxide, chromium oxide, and nickel oxide. The tops of these ingots were forged from the original 2-in. square section to 1-in. square, and longitudinal sections were cut and carefully polished for microscopic examination.

The treatment with alumina was not successful, as this treated bar appeared just as clean as the original steel, so this melt was made over again with the use of metallic aluminium. Characteristic inclusions of alumina were then found in the forged bar, as shown in photomicrograph Fig. 13.

Fig. 14 shows part of a small streak found near the top of the bar made with titanium oxide. The rest of this bar was clean, and the inclusions shown would ordinarily be classed as silicates or slag. They show a peculiar duplex composition and would not be mistaken for alumina.

The steel treated with chromium oxide had small smooth purplish spots scattered all through it, but they were especially segregated in some streaks at the top of the ingot. Some of these inclusions were angular and some rounded, and like alumina they were not elongated by the forging. Where they were not too thickly segregated, however, they took a good smooth polish easily like the silicates, and from this fact and their purplish color they may be easily distinguished from alumina.

The photomicrograph Fig. 15 shows the end of one of the segregated streaks, where small particles of this oxide seem to be breaking away and entering into the steel, and the difference between these and alumina is readily apparent. The steel around these inclusions was very readily stained or tarnished during the polishing, and this effect, though noticed also with the nickel oxide and sometimes with titanium nitride, has not

been seen by the writer around the streaks of alumina.

The last photomicrograph, Fig. 16, shows some of the steel treated with nickel oxide, but these inclusions look exactly like iron oxide, and it may be that the nickel oxide was reduced by the metallic iron present, forming metallic nickel and iron oxide. At any rate these inclusions are entirely different in appearance from alumina. They look very much like sulphides, but are a little darker, and stand out more in relief from the surrounding metal.

The evidence available is thus seen to point uniformly to the conclusion that it is proper to identify as alumina all inclusions, seen in polished steel surfaces, that have exactly the characteristics of the alumina inclusions shown in photomicrographs Figs. 1 and 13. At present no other substance is known to the writer which has the same appearance in a polished steel surface as alumina. Ordinary slag inclusions, as well as the oxides of titanium, chromium and nickel, have been shown to be very different. Of course, there is a possibility that some substance may be found at some future time that has identically the same appearance, but the writer sees no reason to expect such an event, and believes that the work described above renders the identification of alumina in steel with the microscope a matter of as much certainty as the similar identification of sulphides or silicates, which has long been considered reliable.

Physical Testing Laboratory,
Titanium Alloy Manufacturing Co.,
Niagara Falls, N. Y.

Solution Stratification as an Aid in the Purification of Electrolytes*

BY FRANCIS R. PYNE

In the electrolytic refining of copper there are two attendant evils of special prominence. One is the tendency of the electrolyte to stratify or form layers of various compositions, and the other is the accumulation of impurities in the electrolyte.

The stratification is caused by the formation of a heavy solution at the surface of the anode owing to the solution of copper, and by the formation of a lighter solution at the cathode owing to the plating out of copper. Unless the degree of stratification is greatly impeded, the result will be a very unsatisfactory cathode deposit, which will be at best heavy and lumpy at the bottom, while mealy and of poor quality at the top. The greater part of the current will pass through the strata of highest concentration, causing frequent short circuits and uneven dissolving action at the anode, with all the attendant deposition troubles.

As a preventive, the electrolyte is circulated throughout the tanks at a rate which varies with local conditions at each plant. Too rapid a circulation is liable to carry slime, if present, to the cathode, fouling it and causing metal losses in silver and gold. Too slow a circulation does not sufficiently suppress the stratification. Where the current density is high the circulation must be more rapid than would be the case with a lower density.

To show the degree to which stratification will take place, the figures in Table I are taken from a paper by Mr. W. T. Burns on "The Great Falls Electrolytic Plant" (Trans. A. I. Mining Eng., August, 1913). This illustration is selected on account of the high current density in use at Great Falls, 36 amp. per square foot (400 per sq. m.), which is conducive to very marked stratification. Samples of the electrolyte were taken between the center pair of electrodes at the following levels below the solution line: Zone 1, 6 in. (15 cm.); Zone 2, 17 in. (43 cm.); Zone 3, 28 in. (70 cm.); Zone 4, 39 in. (100 cm.).

The figures represent the average of 104 samples taken during seven consecutive days, and the results are reported in grams per liter.

TABLE I

	Zone	Sp. Gr.	Acid	Copper
Circulation at the rate of 6 gal. (23 liters) per minute	1	1 213	174	38 4
	2	1 216	172	39 2
	3	1 216	171	40 2
	4	1 228	153	49 9
Circulation at the rate of 4 gal. (15 liters) per minute	1	1 211	163	40 0
	2	1.214	161	41.1
	3	1 216	159	42 0
	4	1 263	139	67.8
Circulation at the rate of 2 gal. (7.6 liters) per minute	1	1 210	167	37 8
	2	1 213	165	39 0
	3	1 217	162	41.0
	4	1 265	146	66.4
Circulation shut off for seven hours.	1	1 185	179	23.4
	2	1 210	164	38.0
	3	1 230	151	51.8
	4	1 255	138	65.5

The above figures clearly show the increase in stratification with decrease in circulation.

Regarding the accumulation of impurities in the electrolyte, these impurities are present in the anode, whence they pass into solution through the action of the current, or they may come from some outside source, for example, an addition agent. If allowed to accumulate in the electrolyte without restraint they may foul the cathode by being deposited thereon either electrically or mechanically. They may also increase the resistance of the electrolyte causing thereby a loss of power, or they may increase the specific gravity so that the settling of the slime is hindered, with a possible loss of slime in the cathode. In order to prevent these undesirable effects, the impurities in the electrolyte are not permitted to go above certain limits, and this is accomplished by withdrawing a certain amount of electrolyte from time to time for the removal therefrom of the undesirable constituents, and this removal must be done in such a manner that the valuable ingredients, such as copper and acid, shall not be wasted.

The customary method in use at the present time is to withdraw daily from the electrolyte a certain portion which is either worked for bluestone ($CuSO_4.5H_2O$), or else passed through tanks containing insoluble anodes. It is with the latter method that this paper deals. The treatment with insoluble anodes removes a large part of the copper from the electrolyte, but requires a large power expenditure, the output per kilowatt-hour being one to two pounds (0.45 to 0.90 kg.) as against an output of eight pounds (3.63 kg.) in the regular refining tanks. Moreover the quality of the deposited copper is greatly inferior to the regular cathodes.

The solution from this first set of insoluble anode tanks is then passed through a second set, usually at a slower rate of circulation, and this second set of tanks removes the balance of the copper and practically all of the arsenic and antimony. The solution is then treated in any suitable manner for the elimination of such other impurities as may be desired.

From the above it is evident that could a solution be secured from the regular tanks sufficiently low in copper to avoid treatment in the first set of insoluble anode tanks, there would result a considerable saving in power, assuming that it contained practically an undiminished amount of impurities.

*A paper read at the San Francisco meeting of the American Electrochemical Society, Sept. 17, 1915.

Knowing the tendency of the electrolyte to stratify, an endeavor was made to utilize this principle as a means to this end. Accordingly a tank was constructed in which the circulation was so arranged that stratification would readily occur. The electrolyte entered the tank just above the slime and was drawn off through two outlets, one at the solution line, the other just above the slime line and opposite the inlet. (U. S. Patent No. 1,148,798, see Met. & Chem. Nov. 1, '15, Pg. 816.)

The accompanying figure shows a sectional elevation

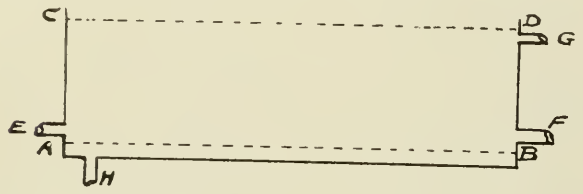


FIG. 1—SHOWING DIAGRAMMATICALLY THE TANK OPENINGS

of the tank as applied to copper refining. *AB* is the slime line, *H* the outlet for removal of slime from the tank, *CD* is the solution line. The electrodes have been omitted for the sake of clearness. The electrolyte enters the tank at *E* and is withdrawn through the upper and lower outlets, *G* and *F* respectively.

If the tank is filled with electrolyte and the upper outlet closed, any solution entering the tank through the inlet *E* will pass directly to the outlet *F* without disturbing the solution in the tank, providing the amount entering and leaving the tank is the same. If, however, the upper outlet *G* is open as well as the outlet *F*, a part of the incoming solution will flow through *F* while the remainder will rise in the tank to take the place of that withdrawn through the outlet *G*.

Now if the electrodes are in place and the normal current is passing and all circulation is stopped, the heavy solution formed at the anode by the copper passing into solution will stream downwards to the bottom of the tank, while the lighter solution at the cathode, due to the removal of the copper from solution, will rise. This is very clearly shown by the test made by Mr. Burns, in which the circulation was stopped for a period of 7 hr. Therefore, there will eventually be a stratum of heavy copper solution around the lower part of the cathode, while the solution in the upper part of the tank will be very low in copper and consequently lighter. The deposit on the lower part of the cathode will be rough and heavy while that on the upper part of the cathode will be loose and mealy.

As stated before, this is a very unsatisfactory condition of affairs, and it is therefore necessary to have such a circulation that the cathode will receive a satisfactory deposit throughout. This is accomplished by so regulating the flow from the upper and lower outlets that the heavy solution at the bottom of the tank will rise to such a height that there is a sufficient amount of copper at all points of the cathode. When proper regulation has been made, the regular tank room solution enters the tank through the inlet *E*, a solution high in copper is withdrawn from the tank through the outlet *F*, while the solution from *G* is low in copper and the cathode is in all respects similar to those drawn from the regular refining tanks.

The low grade solution withdrawn from the outlet *G* has been found in practice to be lower in copper than is usually obtained from the outlet of the first set of insoluble anode tanks mentioned above, and it is delivered directly to the second set of insoluble anode tanks for the removal of the last traces of copper.

The tanks have shown no increase in voltage over that of the regular refining tanks and there is no increase in the labor or material required in their operation. The solution withdrawn from the upper outlet can be varied through quite a range of copper content, and as it is a simple matter to equip a tank for this operation, a large or small number can be kept ready to respond to variations in the amount of solution to be withdrawn from the main circulation. They can be cut in or out at any time and in any part of the circuit, without reference to the age of the copper in the remaining tanks, which must be considered when using insoluble anode tanks unless the latter form a separate section apart from the regular refining tanks. A comparison of the two methods may be seen from the following:

Former Method.—Tank house electrolyte first passed through tanks containing insoluble anodes, to remove a portion of the copper, requiring high power consumption and giving a product of inferior quality, thence to a second set of insoluble anode tanks to remove the remainder of the copper and some of the impurities, after which the solution is treated in any desired manner.

Present Method.—Tank house electrolyte drawn directly from the special stratification tanks, requiring no increase in power and avoiding the production of inferior grades of product; thence to the final insoluble anode tanks, as above.

The net saving is therefore the operation of one set of insoluble anode tanks.

U. S. Metals Refining Company,
Chrome, N. J.

Determination of Mercury in Amalgamation Tailings

At the Buffalo mill, Cobalt, Ontario, Canada, high-grade silver ore is amalgamated in a tube-mill containing a large quantity of mercury and strong cyanide solution. The tailings contain mercury, both metallic and sulphide, which is recovered by dissolution in alkaline sulphide and precipitation with aluminum. The laboratory method of determining mercury in the products of the process is described by E. B. Thornhill in his paper presented to the A. I. M. E. To determine the total mercury (both metallic and sulphide) 0.5 g. of the material is well mixed with cast-iron filings, free from grease, and placed in a hard-glass tube, sealed at one end, with a contraction at about 2 in. from the sealed end. The mercury is distilled off, by heating the bulb containing the charge, and condensed in the tube just beyond the contraction. After the distillation is complete the contracted portion of the tube is heated, the bulb portion pulled off and the end of the tube sealed. The tube containing the condensed mercury is allowed to cool, filled one-half full of 0.1 per cent KCN solution, and 10 to 15 100-mg. gold beads added. Each bead will amalgamate with about 1 mg. of mercury. The tube is shaken until all the mercury is amalgamated; the beads are transferred to a small porcelain cup, washed with water, dried with alcohol and weighed. After retorting off the mercury they are again weighed. From ten to twelve determinations can be made in 1 hr. by this method and it is accurate enough for control of operations.

When it is necessary to know the proportionate amounts of mercury as metallic and sulphide two 2-g. samples are weighed out. One sample is digested with concentrated nitric acid and the other with a 10 per cent solution of sodium sulphide. The mercury in the residue from each is then determined by the method just given.

Flotation at the Consolidated Arizona Smelting Co., Humboldt, Arizona

(Editorial Correspondence)

The introduction of flotation, together with other changes in the milling scheme, at the copper concentrator of the Consolidated Arizona Smelting Co., increased the recovery of copper by more than 20 per cent over the best saving previously made with jigs, tables and vanners. The margin is quite sufficient to represent a difference between profit and loss, particularly when it is accompanied by a simplification of the process and reduction in cost for power and labor.

Milling ore from the company's Blue Bell and DeSoto mines is a silicious sulphide containing pyrite and chalcopyrite in a gangue of quartz and schist. The average composition of the ore and mill products is shown in Table I. In addition to mine ore, a variable quantity of mill tailing from former operations is also reground and concentrated. This material contains about 2 per cent copper.

TABLE I—AVERAGE COMPOSITION, ORE AND MILL PRODUCTS

(Gold and silver in oz. per ton. Other constituents in per cent)

	Au	Ag	Cu	Insol	Fe	CaO	MgO	Al_2O_3	S
Milling ore	0.03	1.3	3.0	65.0	10.9	1.0	1.2	4.7	13.0
Table Conc.	0.09	2.3	7.0	10.0	35.0	..	..	..	...
Table Tailing / Flotation Feed	0.025	1.0	2.1	...	5.8	..	..	..	...
Flotation Conc.	0.10	5.0	14.0	24.0	22.4	..	..	..	...
Gen. Mill Conc.	0.09	3.04	9.52	16.5	30.0	..	..	..	...
Mill Tailing / Flotation Tailing	0.01	0.4	0.3	...	3.0	..	..	..	...

During the month of September, 1915, the total quantity of ore milled was 7173 tons. The average grade of mine ore was 2.7 per cent copper, and of all material, including old tailing, 2.65 per cent. The percentage recovery of valuable metals was 90.9 per cent copper, 68 per cent gold and 72 per cent silver. The gross amount of copper in concentrates was 345,000 lb., of which 240,000 lb., or nearly 70 per cent, was recovered by flotation. The usual recovery by flotation will average about 75 per cent of the total. The ratio of concentration in the entire mill was about 4, and in flotation between 7 and 8.

Effect of Changes in Milling Practice

A diagram of the present flow-sheet is given in Fig. 1. The ore is crushed dry in Blake crusher and rolls, screened in trommels and handled by belt conveyors and elevators in the usual manner. Water is first added at the boot of the main elevator indicated at the right of the diagram. Hardinge mills are used for final grinding, and Wilfley tables and an 11-cell Minerals Separation flotation machine recover the valuable metals.

The changes that have been made during the past year and a half, under the direction of G. M. Colvocoresses, general manager, and J. N. D. Gray, mill superintendent, have been directed toward simplifying and increasing the efficiency of the process, eliminating useless machines and reducing the cost of operation.

By taking out the jigs several beneficial results were obtained. The cost for power and labor was reduced and the general grade of concentrate increased. Also more favorable conditions for flotation were created, because the jigs used a large amount of water which made it difficult to maintain that uniformity in the flow of mill pulp which is essential to good work in flotation. The abandonment of vanners was a natural consequence of the adoption of flotation.

In its present simplified form the milling scheme differs radically from that used in an earlier day. Harz jigs, tables and vanners were formerly used, but the recovery of copper under that system did not exceed 70 per cent, in spite of the complicated treatment to which the ore was subjected. The pyrite, breaking coarser than the chalcopyrite, was easily concentrated, but the softer and more friable copper mineral entailed a heavy loss.

Similar ore conditions prevail to-day; but now the flotation process is effective at the very point in the treatment where tables and vanners proved inefficient. Wilfley tables are now used only for rough concentration, and flotation is relied upon for the major part of copper recovery. Reference to Table I will show that the proportionate iron and copper contents of table and flotation concentrates are reversed. Pyrite concentrates easily on the tables, but floats less readily than chalcopyrite. The flotation product, on the other hand, not only contains twice the percentage of copper found in the table concentrate, but also represents 75 per cent of the total recovery. Furthermore, about 60 per cent of the flotation product is finer than 200-mesh, showing the need of an efficient method of fine concentration if a heavy loss is to be avoided.

Data on Regrinding

Detailed figures on the performance of Hardinge mills are given in Tables II and III. These mills are lined with pebbles set in cement, but a Komata manganese-steel liner is to be given a trial soon. An objection to the present liner is the adverse effect on flotation results, caused by the cement which enters the pulp when a newly lined mill is put in operation. This objection will be overcome by the metal lining.

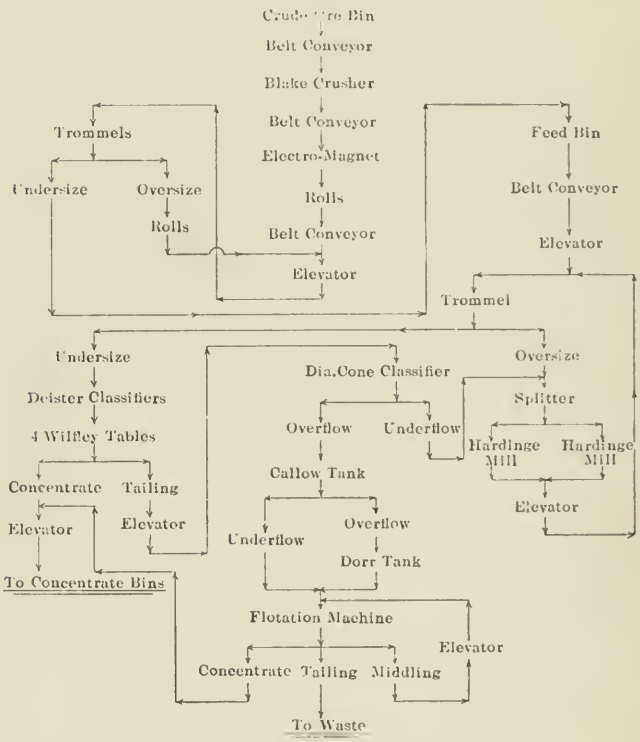


FIG. 1—CONCENTRATOR FLOW SHEET

Selected pieces of copper-bearing rock have been used, instead of pebbles, as the grinding medium. The consumption is indicated in the tables under the headings "Feed to Mill Rock Tons," and "Per Ton Crude Ore." When the Komata lining is installed it is planned to conduct experiments with different grinders—selected ore, chrome-steel balls and "manganoid" balls.

Flotation of Table Tailing

The Consolidated Arizona Smelting Co. was one of the first in this country to adopt the Minerals Separa-

TABLE II. SEPTEMBER HARDINGE MILL RECORD

1915 Date	No. 1 Mill {8 Ft. x 36 In. Belt-Driven 27 R.P.M.} Gradings Inlet + 4	+ 8	+ 14	+ 35	+ 65	+ 100	− 100	Total	Outlet + 35	+ 65	+ 100	+ 200	− 200	Total	Log Per Cent Moisture	Hp.	Feed to Mill Rock Tons	Running Hours
September 1	10.0	16.3	7.5	6.2	11.3	15.0	33.7	100	2.5	15.0	15.0	27.5	40.0	100	34.48	75	3.18	17.08
2	10.0	23.7	11.3	13.7	15.0	10.0	16.3	100	2.5	15.0	15.0	30.0	37.5	100	34.73	71	3.94	20.97
3	6.3	17.5	11.2	12.5	23.7	16.3	12.5	100	7.5	20.0	15.0	25.0	32.5	100	33.65	70	4.50	23.67
4	12.5	20.0	10.0	8.8	17.5	11.2	20.0	100	5.0	20.0	15.0	12.5	47.5	100	33.65	71	4.50	24.00
5	13.7	17.5	8.8	12.5	17.5	10.0	20.0	100	5.0	17.5	15.0	22.5	40.0	100	33.97	75	4.31	24.00
6	17.5	26.2	12.5	11.2	10.0	8.8	13.8	100	5.0	15.0	12.5	25.0	42.5	100	34.23	75	4.31	24.00
7	21.3	32.5	12.5	8.7	8.7	5.0	11.3	100	2.5	10.0	12.5	27.5	47.5	100	34.52	74	3.94	21 42
8	13.7	21.3	11.3	8.7	13.7	10.0	21.3	100	2.5	12.5	15.0	27.5	42.5	100	35.09	75	4.06	22.33
9	16.3	25.0	13.7	13.7	10.0	7.5	13.8	100	5.0	12.5	12.5	27.5	42.5	100	34.94	75	2.25	11.92
10	26.3	32.5	11.3	8.7	6.3	3.7	11.2	100	2.5	12.5	12.5	27.5	45.0	100	34 52	75	2.96	17.58
11	18 7	22.5	10.0	13.8	11.3	11.2	12.5	100	2.5	10.0	15.0	30.0	42.5	100	34.57	75	4.00	24.00
12	15 0	21.2	10.0	15.0	15.0	11.3	12.5	100	2.5	15 0	15.0	27.5	40.0	100	34.96	75	3.87	23.78
13	17.5	25.0	12.5	12.5	11.3	7.5	13.7	100	2.5	10.0	15.0	30.0	42.5	100	34.91	75	4.50	24 00
14	22 5	25.0	10.0	13.7	11.3	6.3	11.2	100	2.5	12.5	12.5	30.0	42.5	100	35.00	75	4.50	24 00
15	11.3	15.0	10.0	15.0	20.0	15.0	13.7	100	2.5	12.5	15.0	27.5	42.5	100	34.93	75	4.50	24.00
16	13.7	18.8	8.7	15.0	17.5	15.0	11.3	100	2.5	15.0	17.5	27.5	37.5	100	34.96	75	4.50	24.00
17	15.0	21.3	10.0	11.3	17.5	13.7	11.2	100	2.5	15.0	17.5	27.5	37.5	100	34.71	75	4.50	23.83
18	18.7	23.7	10.0	13 8	12.5	7.5	13.8	100	10.0	17.5	15.0	25.0	32.5	100	34.89	75	4.50	24.00
19	10 0	17.5	8.7	12.5	28.8	8.7	13.8	100	2.5	12.5	15.0	30.0	40.0	100	34.55	75	4.50	23.94
20	18.8	25.0	10.0	16.0	16.2	8.8	11.2	100	2.5	12.5	15.0	27.5	42.5	100	35.21	75	4.50	23.83
21	10.0	17.5	8.7	11.3	25.0	10.0	17.5	100	2.5	10.0	12.5	27.5	47.5	100	34.67	75	4.50	24.00
22	11.3	25 0	11.2	11.2	17.5	7.5	16.3	100	5.0	15.0	15.0	25.0	40.0	100	34.98	75	4.50	24.00
23	15.0	25.0	10.0	11.3	17.5	7.5	13.7	100	2.5	17.5	17.5	25.0	37.5	100	34.74	75	3.94	22.42
24	22.5	27.5	11.3	11.2	12.5	6.3	8.7	100	2.5	12.5	15.0	30.0	40.0	100	35.05	75	4.50	24.00
25	10.0	15.0	7.5	8.7	21.3	16.3	21.2	100	5.0	15.0	15.0	25.0	40.0	100	34.72	75	4.31	23.92
26	16.2	30.0	11.3	10.0	15.0	6.3	11.2	100	5.0	15.0	15.0	27.5	37.5	100	34.99	75	4.13	23.58
27	12.5	22.5	10.0	11.3	20.0	10.0	13.7	100	5.0	17.5	17.5	25.0	35.0	100	34.57	76	4.31	24.00
28	11.3	18.7	10.0	15.0	20.0	11.2	13.8	100	0.0	7.5	12.5	30.0	50.0	100	34.64	75	4.50	24.00
29	16.3	26.2	10.0	8.7	13 8	11.3	13.7	100	5.0	17.5	15.0	25.0	37.5	100	34.85	75	2.56	15.17
30	13.7	22.5	8.8	13.7	20.0	7.5	13.8	100	2.5	17.5	15.0	25.0	40.0	100	34.48	75	4.50	24.00
Total																	123.57	
Average	14.9	22.6	10.3	11.7	15.9	9.9	14.7	100	3.6	14.3	14.7	26.7	40.7	100	34.67	74.6	4.12	22.51
Per ton crude ore																	68.8 lb.	

1915 Date	No. 2 Mill {8 Ft. x 36 In. Direct-Geared 23 R.P.M.} Gradings Inlet + 4	+ 8	+ 14	+ 35	+ 65	+ 100	− 100	Total	Outlet + 35	+ 65	+ 100	+ 200	− 200	Total	Log Per Cent Moisture	Hp.	Feed to Mill Rock Tons	Running Hours	Total per Cent Running Time
September 1	16.3	35.0	15.0	7.5	7.5	6 2	12.5	100	2 5	12.5	12.5	32 5	40.0	100	35.19	65	3.38	18.58	71 4
2	11.3	33.7	18.7	15 0	10.0	5.0	6 3	100	5 0	17.5	15 0	25.0	37 5	100	34.82	65	2.69	14.13	73.1
3	7.5	22.5	13.7	16.3	18.7	13.8	7.5	100	10.0	22 5	15 0	22.5	30.0	100	33.87	65	4 50	24 00	99.4
4	18.7	26.3	12.5	13.7	11.3	7.5	10.0	100	5.0	17.5	15 0	22.5	40.0	100	34.48	65	4 50	24 00	100.0
5	15.0	21.3	10.0	12.5	16 2	13.7	11.3	100	5.0	20.0	15 0	22.5	37.5	100	34.13	65	4.31	24.00	100 0
6	17.5	28.8	13.8	11.2	10.0	7.5	12.5	100	2.5	10.0	12.5	30.0	45 0	100	35.05	65	4 14	23 58	99 0
7	15.0	25.0	12.5	10.0	11.3	7.5	16.2	100	2.5	10.0	12.5	27.5	47 5	100	35.29	65	3 94	21 42	89.2
8	13.7	22.5	11.3	10.0	12.5	10.0	20.0	100	2.5	12.5	12.5	27.5	45 0	100	35.57	65	3.50	19 50	87.1
9	10.0	23.7	13.7	16.3	10.0	5 0	3.7	8.8	100	2.5	10.0	12.5	27.5	47.5	100	35.26	65	2 25	12 58	51.0
10	6.3	18.5	8.5	7.2	2.5	2.5	5 0	100	2.5	15 0	15.0	27.5	40 0	100	35.13	65	4 06	23.83	85 9
11	11.3	16.2	6.3	11.3	17.5	11.2	12.5	100	2.5	7.5	12.5	32.5	45 0	100	35.12	65	4.00	24.00	100 0
12	11.3	16.3	11.2	8 7	6 3	10 0	100	2.5	7.5	12.5	30 0	47.5	100	35.56	65	3 88	23.95	99 5
13	11.3	16.3	11.2	8.7	6.3	10 0	100	2.5	12.5	15 0	27.5	42 5	100	35.32	65	4 13	24 00	103.0
14	13.7	16.3	11.2	8.8	5.0	10.0	100	2.5	10 0	12.5	30 0	45 0	100	35.20	65	4 50	24 00	100 0
15	13.8	15.0	11.2	8.7	6.3	10 0	100	2 5	7.5	12.5	30.0	47.5	100	35 59	65	4 50	24 00	100 0
16	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	10 0	15 0	30.0	42 5	100	35.35	65	4 50	24.00	100 0
17	15.0	16.3	11.2	8.7	6.3	10.0	100	0 0	10.0	12.5	30.0	47.5	100	36.91	65	3 38	18 67	88 5
18	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	12.5	15 0	27.5	42 5	100	35.32	65	4 50	24 00	100 0
19	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	10.0	15 0	30.0	42 5	100	35.51	65	4 50	23 94	99.7
20	13.7	16.3	11.2	8.7	6.3	10.0	100	0 0	7.5	12.5	30.0	50.0	100	35.50	65	4.50	23 33	98 3
21	13.7	16.3	11.2	8.7	6.3	10.0	100	2 5	15 0	15 0	25.0	42 5	100	35 56	65	4 50	24.00	100.0
22	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	12.5	12.5	27.5	45.0	100	35.35	65	4.50	24.00	100 0
23	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	12.5	15.0	27.5	42.5	100	35.21	65	4.31	24.00	96.7
24	13.7	16.3	11.2	8.7	6.3	10.0	100	5.0	17.5	15.0	22 5	40.0	100	35.52	65	4.50	24.00	100 0
25	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	10.0	12.5	27 5	47.5	100	35.44	65	4 31	23.92	99.8
26	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	12 5	15.0	27.5	42.5	100	35.53	65	4 13	24.00	99.1
27	13.7	16.3	11.2	8.7	6.3	10.0	100	2.5	10.0	15.0	27.5	45 0	100	35.51	65	4 31	24.00	100 0
28	13.7	16.3	11.2	8.7	6.3	10.0	100	5.0	17 5	17.5	27.5	32.5	100	35.49	65	4 50	23.58	99.1
29	13.7	16.3	11.2	8.7	6.3	10.0	100	0.0	7 5	12.5	32.5	47.5	100	35.59	65	2.75	15.83	64.6
30	13.7	16.3	11.2	8.7	6.3	10.0	100	0.0	7 5	12.5	30.0	50.0	100	35 44	65	4 50	23 67	99.4
Total																	121.97	
Average	11.9	22.6	12.9	12.4	14.0	8.4	10.9	100	2.8	12 2	13.8	27 9	43.3	100	35.29	65	4.07	22.35	93.4
Per ton crude ore																	68.4 lb.		

TABLE III—GENERAL HARDINGE MILL RECORD

1915	No. 1 Mill Gradings Inlet + 4	+ 8	+ 14	+ 35	+ 65	− 65	Total	Outlet + 35	+ 65	+ 100	+ 200	− 200	Total	Log Per Cent Moisture	Hp.	Feed to Mill Tons Rock	Feed to Mill Per Ton Crude Ore	Running Hrs.
January	15 2	19.2	10.8	20 6	17.0	17.2	100	14.2	22.4	12.1	17.2	34.1	100	37.99	61	138.23	Lb. 73.3	22.31
February	13.8	19.3	12.3	21.3	16.9	16.4	100	15.4	24.2	12.4	14.1	33.9	100	38.25	62	104.62	69.0	19.60
March	13.4	22.8	12.4	16.0	17.3	18.1	100	8.9	21.9	14.0	19.1	36.1	100	38.29	67	134.68	78.4	22.77
April	15.6	23.0	10.9	17.7	19.7	13 1	100	11.7	28.0	13.8	20.2	26.3	100	36.66	72	129.14	59.0	22.52
May	19.0	26 2	12.7	14.5	14.3	13.3	100	6.6	19.4	14.4	23.0	36.6	100	36.55	70	129.15	74.8	20.46
June	15.6	21.5	11.2	16.3	19.0	16.4	100	7.1	21.1	15.7	22.6	33.5	100	35.39	75	126.95	61.2	22.9
July	9.6	21.4	12.9	19.1	19.7	17.3	100	8.6	22.0	14.5	20.5	34.4	100	35.23	74.3	116.35	66.5	21.26
August	9.1	21.1	12.0	18.9	22.7	16.2	100	6.7	21.8	15.9	21.0	34.6	100	35.21	72.8	117.90	61.0	21.69
September	+4 14.9	+8 22.6	+14 10.3	+35 11.7	+65 15.9	+100 9.9	−100Total 14.7 100		3.6	14.3	14.7	26.0	40.7	100	34.67	74.6	123.57	68.8	22.51

1915	No. 2 Mill Gradings Inlet + 4	+ 8	+ 14	+ 35	+ 65	− 65	Total	Outlet + 35	+ 65	+ 100	+ 200	− 200	Total	Log Per Cent Moisture	Hp.	Feed to Mill Tons Rock	Feed to Mill Per Ton Crude Ore	Running Hrs.	Total per Cent Running Time
January	18.1	20.5	11.6	19.8	13.6	16.4	100	16.9	21.6	10.9	16.6	34.0	100	37.88	62	92.70	Lb. 71 4	15.41	78.6
February	16.5	20.6	11.6	20.4	15.7	15.2	100	15.6	24.8	11.9	14.7	33.0	100	37.98	60	99.76	72.0	17.78	77.8
March	14.8	24.0	12.3	16.1	15.9	16.9	100	7.7	22.1	14.1	19.0	37.1	100	38.33	61	116.79	78 5	19.78	88.7
April	15.0	22.6	11.6	16.3	18.6	15.9	100	7.9	23.9	14.3	23.2	30.7	100	38.59		35.20	57 2	6.32	60.1
May	16.0	24.6	13.1	15.9	15.7	14.7	100	4.3	17.2	15.1	24.9	38.5	100	37.49	60	37.49	70.7	19.00	82.2
June	15.2	21.4	11.7	16.7	18.2	16.8	100	5.6	20.1	15.6	23.4	35.3	100	35.36	65	103.80	61.6	18.61	86.5
July	8.5	20.7	12.6	19.8	20.5	17.9	100	7.4	21.4	15.1	20.7	35.4	100	35.21	65	116.05	66.4	21.26	88.6
August	11.0	23.9	13.3	17.5	18.3	16.0	100	5.6	20 6	15.8	22.4	35.6	100	35.35	69.4	106.47	67.6	20.37	83.6
September	+4 15.0	+8 26.4	+14 12.9	+35 12.4	+65 14.0	+100 8.4	−100Total 10.9 100	2.8	12.2	13.8	27.9	43.3	100	35.29	65	121.97	68.4	22.35	93.4

TABLE IV—SEPTEMBER FLOTATION RECORD

1915		DAILY																		WEEKLY																			
		FEED GRADINGS					OIL CONSUMPTION, LB.				ASSAY VALUES									GRADINGS																			
																				FEED								TAILING											
	Date	+35	+65	+100	+200	−200	Total	Stove Oil	Refined Creosote Oil	Fuel Oil	Total	Per Cent Running Time	Density Ratio of H_2O to Dry Ore	Feed Cu	Concentrates Cu	Concentrates Insol.	Tail Cu	Ratio of Conc.	Per Cent. Recovery		+35	+65	+100	+200	−200	Total		+35	+65	+100	+200	−200	Total							
September	1	0.0	5.0	10.0	32.5	52.5	100	120	60	7	187	79.6	2.6	1.96	13.00	24.4	0.28	7.6	87.7	% solids....	2.5	10.0	10.0	26.3	51.2	100.0	% solids....	0.0	5.0	10.0	32.5	52.5	100							
	2	0.0	7.5	10.0	30.0	52.5	100	126	63	14	203	99.9	2.7	2.16	13.60	29.2	0.38	7.4	84.7	Assay value.	1.18	1.24	1.16	1.50	2.80	2.098	Assay value.	0.0	2.5	10.0	30.0	52.5	100							
	3	2.5	15.0	12.5	22.5	47.5	100	129	64	7	200	100.0	1.9	1.98	15.76	23.2	0.34	9.4	84.6	% Cu.....	1.4	5.9	5.5	18.8	68.4	100 0	% Cu.....	0.0	2.5	12.5	22.5	47.5	100							
	4	5.0	15.0	12.5	22.5	45.0	100	123	62	13	198	100.0	1.9	2.16	16.04	22.8	0.26	8.3	89.4																				
	5	0.0	5.0	12.5	30.0	52.5	100	121	61	9	191	100.0	1.9	2.04	16.72	24.0	0.26	9.3	88.6	% solids....	2.5	7.5	10.0	23.7	56.3	100.0	% solids....	0.0	5.0	10.0	25.0	56.2	100.0	0 12	5 00	15 20	0 03	1 00	2 14	0 01	0 35	0 37
	6	2.5	7.5	10.0	22.5	57.5	100	143	72	10	225	100.0	1.3	2.28	15.16	26.2	0.37	7.8	86.0	Assay value.	1 32	1.04	0.98	1.50	2.72	2.906	Assay value.	0.0	2.5	7.5	22.5	67.5	100									
	7	2.5	5.0	7.5	30.0	55.0	100	116	58	7	181	95.0	2.3	2.22	15.28	23.2	0.37	8.1	85.4	% Cu.....	1.6	3.7	4.7	17.0	73.0	100 0	% Cu.....	0.0	1.6	3.7	19.1	73.2	100 0	0 12	5 00	15 20	0 03	1 00	2 14	0 01	0 35	0 37
	8	2.5	7.5	10.0	25.0	55.0	100	161	52	6	213	88.5	1.9	2.06	14.44	26.0	0.39	8.4	83.3																				
	9	2.5	7.5	7.5	22.5	60.0	100	110	35	5	150	55.0	2.9	2.02	14.88	23.8	0.31	8.5	86.4																				
	10	2.5	5.0	10.0	30.0	52.5	100	178	58	3	239	100.0	2.1	2.04	14.60	23.6	0.40	8.9	80.1																				
	11	2.5	5.0	10.0	30.0	52.5	100	123	61	8	192	100.0	1.9	2.16	14.84	23.0	0.36	8.0	85.6																				
	12	2.5	10.0	12.5	25.0	50.0	100	123	61	7	191	99.8	1.9	2.10	16.52	21.2	0.37	9.3	84.2	% solids....	1.3	6.2	10.0	27.5	55.0	100.0	% solids....	0.0	2.5	10.0	27.5	60.0	100									
	13	0.0	5.0	7.5	30.0	57.5	100	139	69	13	221	100.0	1.9	2.52	14.44	21.2	0.43	6.7	85.5	Assay value.	1.14	0.90	0.88	1.44	2.76	2.073	Assay value.	0.0	2.5	7.5	22.5	67.5	100									
	14	2.5	7.5	10.0	27.5	52.5	100	133	67	11	211	100.0	1.9	2.04	16.04	23.0	0.49	10.0	78.4	% Cu.....	0.7	2.7	4.3	19.1	73.2	100 0	% Cu.....	0.0	1.6	3.7	19.1	73.2	100 0	0 13	5 10	15 48	0 04	0 95	2 12	0 02	0 41	0 39
	15	0.0	5.0	7.5	32.5	55.0	100	157	78	6	241	100.0	2.1	2.16	15.44	25.6	0.36	8.0	89.5																				
	16	2.5	5.0	7.5	27.5	57.5	100	194	63	6	263	100.0	2.2	2.24	15.80	23.2	0.35	8.2	86.4																				
	17	0.0	7.5	12.5	32.5	47.5	100	235	74	13	322	99.2	2.2	1.82	14.36	26.6	0.27	9.1	86.6																				
	18	0.0	2.5	10.0	30.0	57.5	100	231	73	11	315	100.0	2.0	2.02	15.16	27.2	0.42	9.2	81 4																				
	19.	0.0	5.0	10.0	32.5	52.5	100	138	69	21	228	99.9	2.2	1.98	15.80	22.4	0.32	9.3	85.5	% solids....	1.3	5.0	11.3	31.2	51.2	100.0	% solids....	0.0	5.0	11.3	38.7	45.0	100.0									
	20.	0.0	5.0	10.0	30.0	55.0	100	151	76	21	248	99.2	2.0	1.78	15.04	26.2	0.27	9.8	86.4	Assay value.	1.84	0.92	0.84	1.48	2.66	1.989	Assay value.	0.0	2.5	7.5	23.2	68.5	100.0									
	21.	0.0	2.5	7.5	27.5	62.5	100	207	103	23	333	100.0	2.1	2.12	14.40	26.6	0.23	7.5	90 4	% Cu.....	1.2	2.3	4.8	23.2	68.5	100 0	% Cu.....	0.0	1.2	2.3	14.0	68.5	100.0	0 13	5 13	15 20	0 03	0 87	1 96	0 02	0 28	0 23
	22.	5.0	10.0	27.5	52.5	100	242	148	74	20	242	100.0	2.0	2.18	15.24	26.2	0.21	7.6	91.6																				
	23	0.0	5.0	12.5	35.0	47.5	100	239	75	14	328	100.0	2.1	1.84	14.76	25.7	0.23	9.0	88.8																				
	24	0.0	2.5	12.5	37.5	47.5	100	234	72	18	324	100.0	2.2	1.92	15.00	26.0	0.26	8.9	88.0																				
	25	2.5	7.5	12.5	30.0	47.5	100	273	87	11	371	99.2	2.2	1.96	14.80	26.0	0.24	8.5	89 3																				
	26.	0.0	2.5	10.0	35.0	52.5	100	148	74	14	236	100.0	2.2	1.92	13.92	28.6	0.29	8.4	86.7	% solids....	1.5	6.7	10.5	29.5	51.8	100.0	% solids....	0.0	5.0	11.3	38.7	45.0	100.0									
	27.	2.5	5.0	10.0	30.0	52.5	100	149	75	15	239	100.0	2.1	2.16	14.60	25.6	0.26	7.5	89.5	Assay value.	1.10	0.98	0.93	1.50	2.71	2.035	Assay value.	0.0	2.5	7.5	23.2	68.5	100.0									
	28.	0.0	2.5	7.5	35.0	55.0	100	169	84	15	268	100.0	2.2	2.04	14.56	26.0	0.24	8.0	89.6	% Cu.....	1.0	3.3	4.8	22.0	68.9	100 0	% Cu.....	0.0	1.6	3.7	19.1	73.2	100 0	0 13	5 10	15 48	0 04	0 95	2 12	0 02	0 41	0 39
	29.	0.0	7.5	12.5	32.5	47.5	100	116	58	10	184	65.0	2.0	1.82	13.44	29.2	0.32	8.8	84.4																				
	30.	0.0	5.0	12.5	32.5	50.0	100	191	96	19	306	100.0	2.1	1.66	12.76	30.8	0.27	9.0	85.7																				
Total, lb.....		1 3	6.1	10.3	29.6	52	7 100.0	4149	2074	357	6580		2.1	2.07	14.88	25.2	0.32	8.5	86.3	% solids....	1.5	6.7	10.5	29.5	51 8	100 0	1.0	6 2	9.2	28.3	55 3	100 0									
Averages.....																				Assay value.	1.10	0.98	0.93	1.50	2.71	2.035	0.61	0.76	0.51	0.35	0 27	0 329	0 12	4 85	14 86	0 03	0 88	2 03	0 016	0 31	0 32
Gallons.....								583	255	48	886	96.01								% Cu.....	1.0	3.3	4.8	22.0	68.9	100 0	2 9	14 4	14 6	22.1	46.0	100 0									

Tons crude ore milled, 7173. Pounds oil used, 6580. Pounds oil per ton crude ore, 0.917. Cost oil per pound, 2.8 cents

tion process of flotation, producing a mineral-bearing froth by violent agitation. No acid is used and the work is done at mill temperature. The flotation feed is table tailing thickened to the desired consistency by means of cones and Dorr thickener. The diaphragm cone cuts out some coarse ore for regrinding. The Callow tank removes sand from the feed to the Dorr thickener so that the latter machine will not become overloaded. The thickened pulps from both the Callow tank and Dorr thickener are combined for flotation treatment.

Oil is added continuously to the inflowing pulp and the mixture then passes successively through the 11 cells of the machine. There is no retreatment or cleaning of concentrate, the froths from all cells being combined. The overflow of the last spitzkasten is regarded as a middling and is returned to the machine. The underflow from the last spitzkasten is final tailing.

All of the essential data on flotation at this mill are embodied in Tables IV and V, which require little explanation. Referring to the weekly gradings and analyses of feed and tailing, "per cent solids" indicates the customary screen analysis; "assay value," the actual percentage of copper in each grade, and "per cent copper," the proportionate percentage of total copper represented by each grade. Examination of these figures for "feed" will show that the actual copper content increases with the fineness of the grade; and since the major portion of the pulp is ground to minus 200-mesh, the greatest proportionate percentage of total copper is carried in the finest material. In Table V attention should be directed to the percentage recovery for January, which is much lower than for other months on account of the treatment at that time of a large quantity of oxidized ore. The treatment of this material resulted from an accident to the hoist at the Blue Bell mine, which prevented the usual production of ore for several weeks, and necessitated filling the mill bins very largely with oxidized material from surface dumps. In June a somewhat similar condition arose for a short period, and some oxidized material again found its way to the flotation department.

Ever since flotation has been in use here, it has been necessary

TABLE V—GENERAL FLOTATION RECORD

DAILY — WEEKLY

1915	Feed Gradings: +35	+65	+100	+200	−200	Total	Density Ratio of H_2O to Dry Ore	Oil Consumption: Stove Oil	Creosol	Crude Turps	#11 Tar Oil	Carbolic	Other Oils	Total	Lb. per Ton Ore	Assay Values: Feed, Cu.	Tail, Cu.	Concentrate: Cu.	Concentrate: Insol.	Ratio of Conc.	Per Cent Recovery	Gradings: Feed:	+35	+65	+100	+200	−200	Total	Tailing: +35	+65	+100	+200	−200	Total	Concentrate: Au	Concentrate: Ag	Concentrate: Cu	Concentrate: Total	Assay Values: Feed: Au	Feed: Ag	Feed: Cu	Tailing: Au	Tailing: Ag	Tailing: Cu
Jan.	1	10	10	22	56	100	2	1844	195	1150	239	945		4373	0	661	2	47	0	935	15	82	31	2	10.3	66.2	0.4	8.9	10.0	20.7	60.0	100	0.7	10.5	11.2	22.9	54.7	100	0.07	4.10	15.90	0.97	0.025	0.97	2.46	0.018	0.57	0.94
																											1.06	1.08	1.75	2.49	2.82	2.45	0.85	0.97	1.22	1.04	0.89	0.97										
																											0.2	4.0	7.1	21.0	67.7	100	0.2	4.0	7.1	21.0	67.7	100										
Feb.	1	3	10	7	11	100	2	2652	1643	1643	326			6264	1	080	2	59	0	32	16	66	25	9	7.3	89.4	1.2	10.0	10.9	19.4	58.5	100	0.73	2.8	11.3	12.2	20.0	55.3	100	0.06	3.68	16.38	0.32	0.016	0.68	2.61	0.0075	0.27	0.32
																											0.84	1.05	1.88	2.95	2.91	2.60	0.17	0.81	0.59	0.27	0.17	0.32										
																											0.40	4.1	8.0	22.0	65.5	100	2.8	23.6	22.5	16.7	29.3	100										
March.	0	3	8	6	11	100	2	2691	1637	1629	325			6192	0	928	2	36	0	37	17	20	23	7	8.5	86.3	0.2	8.8	12.2	21.0	57.8	100	0.2	8.7	11.8	23.3	56.0	100	0.095	5.20	16.86	0.38	0.023	1.00	2.31	0.01	0.39	0.37
																											0.18	0.92	1.55	2.31	2.69	2.30	0.14	0.72	0.62	0.35	0.29	0.38										
																											0.1	3.5	8.2	20.8	67.4	100	0.3	17.3	20.0	21.4	41.0	100										
April	0	0	8	2	12	100	2	2675	1678	1359	396	8	383	6499	1	158	2	12	0	28	14	28	23	0	7.8	88.5	0.0	6.2	12.6	27.2	54.0	100	0.0	0.58	13.5	28.5	51.3	100	0.106	4.63	13.82	0.25	0.022	0.93	2.13	0.01	0.34	0.29
																											0.0	0.79	1.24	1.97	2.56	2.14	0.0	0.49	0.23	0.23	0.21	0.28										
																											0.0	2.3	7.3	25.9	64.5	100	0.0	23.6	23.7	38.9	100										
May	0	0	3	8	9.9	100	2	2738	1571	1563	315	28	485	6700	0	995	2	22	0	29	13	2	22.4	6.8	88.9	0.0	5.3	10.0	29.7	55.0	100	0.0	7.8	12.8	27.5	51.9	100	0.11	4.35	13.28	0.31	0.025	0.95	2.25	0.011	0.37	0.31
																											0.0	0.87	1.29	1.92	2.68	2.23	0.0	0.71	0.42	0.23	0.23	0.31										
																											0.0	2.1	5.8	25.7	66.4	100	0.0	18.5	21.5	20.4	39.6	100										
June	0	0	1	5	2	100	2	2014	974	1451	311	478	287	5515	0	732	2	10	0	46	13	89	24	4	8.2	80.8	0.2	7.5	12.0	29.3	51.0	100	0.0	7.0	12.7	29.5	50.8	100	0.11	4.22	13.88	0.50	0.030	0.92	2.16	0.017	0.45	0.48
																											0.30	0.91	1.17	1.82	2.08	2.11	0.0	0.63	0.67	0.43	0.48	0.50										
																											0.1	3.2	6.6	25.1	65.0	100	0.0	8.9	17.3	24.9	48.9	100										
July	0	0	4	4	11	100	2	3644	529	538	107	200 Oil 1705 Cu	332	6855	0	948	2	09	0	26	13	90	26	8	7.5	89.0	0.0	5.2	12.0	30.0	52.8	100	0.0	5.61	2.02	9.6	52.8	100	0.11	4.38	14.00	0.30	0.024	0.88	2.04	0.011	0.34	0.28
																											0.0	0.75	0.94	1.77	2.65	2.08	0.0	0.56	0.41	0.26	0.25	0.30										
																											0.0	1.9	5.4	25.7	67.0	100	0.0	10.5	19.9	26.4	43.2	100										
August	0	2	5	1	12	100	2	4074	442	443	91	1677	353	7080	1	034	2	11	0	27	13	99	26	8	7.4	88.8	0.0	4.5	11.5	26.7	57.3	100	0.0	4.8	11.7	28.8	54.7	100	0.104	4.46	14.13	0.275	0.024	0.90	2.14	0.011	0.30	0.27
																											0.0	0.80	0.92	1.65	2.74	2.14	0.0	0.61	0.48	0.25	0.21	0.275										
																											0.0	1.7	5.1	20.1	73.1	100	0.0	10.4	20.5	26.5	42.6	100										
Sept.	1	3	6	1	10	100	2	4149	...	...	...	2074	357	6580	0	917	2	07	0	32	14	88	25	2	8.5	86.3	1.5	6.7	10.5	29.5	51.8	100	1.0	6.2	9.2	28.3	55.3	100	0.12	4.85	14.86	0.329	0.030	0.88	2.03	0.016	0.31	0.32
																											0.10	0.98	0.93	1.59	2.71	2.035	0.61	0.76	0.51	0.25	0.27	0.329										
																											1.0	3.3	4.8	22.0	68.9	100	2.9	14.4	14.6	22.1	46.0	100										

to pay the closest attention to the chemical condition of the ore. A splendid recovery is made on clean, bright, fresh sulphides, but when the minerals become tarnished or suffer surface oxidation to a slight extent, or if the gangue becomes oxidized and forms decomposition products such as oxide of iron and carbonate of magnesia, the flotation froth is almost immediately "killed" and a serious drop in percentage recovery is noted. Extreme care is used, therefore, to send to the mill only clean sulphide ore. Oxidized material from the upper levels of the mine is smelted directly or, if it is high in silica, it is used for converter flux and fettling.

The reduced recovery of January and June due to the involuntary treatment of oxidized material, is clearly shown in the flotation record, Table V, and in total mill recovery, Table VI.

TABLE VI.

Total Mill Recovery.

1915	Per cent Copper.
January	74.6
February	91.6
March	90.2
April	92.7
May	92.7
June	86.2
July	92.2
August	92.0
September	90.9

In Table V will be seen the variety of oils and mixtures tested with a view to getting the best metallurgical results with the cheapest materials. In July and subsequent months, "No. 200 oil" (refined wood creosote) has replaced cresol, turpentine and tar oil, with a consequent increase in stove oil, a cheaper oil. The mixture is now two parts stove oil and one part No. 200 oil.

Cost of Flotation

The total cost of concentration, including coarse crushing and flotation royalty, is slightly over $1 per ton. In September it was $1.03. The cost of the flotation process, exclusive of royalty, has been $0.27 per ton over a period of six months. The oil cost has been gradually reduced to 2.8 cents per pound,[1] and the consumption averages a little less than one pound per ton of crude ore. The power consumed by the flotation machine for a period of 24 hours is 32.7 kw.

The record recovery in January made at this plant are but part of a comprehensive plan laid out by the management for placing the company's entire property—mines, concentrator and smelter—on an economic and profitable basis. The foregoing data on the mill speak for themselves and indicate the vast

[1]Pounds per gallon: Stove oil, 7.12; wood creosote, 8.25; fuel oil, 7.48.

improvement that has already been made. With the anticipated development of the mines and increased mill capacity it is expected that the tonnage treated will be increased from 225 to 400 tons per day and that the cost for milling will be reduced from about $1 to under $0.90 per ton. In a later issue we shall publish some notes on the smelting practice at Humboldt.

To Mr. Colvocoresses and members of his staff we are indebted for many courtesies extended and for permission to publish valuable and timely data on the flotation of copper ores.

The Treatment of Sewage by Aeration in the Presence of Activated Sludge*

BY EDWARD BARTOW

Director of the Illinois State Water Survey

Sewage treatment by aeration in the presence of sludge is the latest development in sewage disposal. Air has always played an important rôle in sewage disposal. The earliest application of air was the exposure of sewage on the ground or in shallow pools. The disposal of sewage by irrigation is, therefore, an aeration process. No more sewage can be added to land than can be thoroughly oxidized. The disposal of sewage by dilution in streams also depends on the amount of air present. The amount of sewage which can be purified by a stream is limited by the amount of dissolved oxygen present. The efficiency of the stream depends upon the amount of water or the amount of oxygen in solution or the possibility of reaeration.

Intermittent sand filtration, where sewage is added intermittently to sand beds, is an aeration process, for between the periods of flooding with sewage, air is allowed to enter the pores of the sand. The action of contact beds is of a similar nature. Coarser material is used and between the periods of flooding, air enters the interstices and is the purifying agent. Sprinkling filters, the most practical process up to the time of the suggestion of activated sludge, depend upon aeration accomplished by spreading the sewage in a finely divided state into the air.

Preliminary to these aeration processes preparatory treatment is necessary. Preparatory treatment consists in using screens, grit chambers, settling tanks, digestion tanks or chemical precipitation. The preparatory treatment varies according to conditions. For example, three cities visited in Europe use different degrees of preparatory treatment prior to disposal by dilution. Munich uses no screening whatever, the water in the Iser being of sufficient quantity and sufficiently aerated to dispose of the sewage. Hamburg can dispose of its sewage in the lower Elbe using only coarse screening, but Dresden on the upper Elbe must pass its sewage through fine screens before emptying it into the river.

Grit chambers and settling tanks remove suspended matter. The amount of purification is comparable with the amount of purification by screening.

Digestion tanks accomplish the partial destruction of the suspended solids and soluble organic matter by anaerobic bacteria.

The addition of chemicals assists sedimentation and retards digestion, giving an increased amount of sludge, but a much improved effluent. Neither the screening nor the sedimentation nor the digestion nor the chemical precipitation produce complete purification. Aeration processes must complete the purification.

The latest process, the aeration of sewage in the presence of sludge, has had a gradual development. Numerous experiments of blowing air into sewage have been made both in America and in Europe. Until recently none of the experiments were at all promising and the conclusion was that such means of purification was not practical. In this country, the first promising method was that used by Black and Phelps[1] in New York. They blew air through the sewage as it passed over a series of inclined wooden gratings. This sewage was in contact with the air for varying periods up to twenty-four hours. The results were promising enough to cause Black and Phelps to recommend the construction of a larger plant for Greater New York. That plant has not been constructed and the experimental tank has been adapted to experiments with activated sludge.

The next experiments are those reported by Clark and Gage and Adams[2] at the Massachusetts State Board of Health Experiment Station in Lawrence. Air blown through sewage reduced the organic constituents. The seeding of the sewage with green growths accelerated the action. Their best results were obtained when the tank contained slabs of slate covered with a brown growth of sewage matters. This treatment produced an effluent which could be filtered at several times the normal rate. It, however, simply prepared the sewage for addition to sand beds, and was not considered a final process.

Gilbert J. Fowler of the University of Manchester was in this country in November, 1912, in connection with the disposal of the sewage of Greater New York, and visited the Massachusetts Experiment Station. Fowler and Mumford carried on experiments with a specific bacillus, which they named M-7, which was collected from the waste water from a colliery. This bacillus with aeration has the power of separating iron as ferric hydroxide from iron-bearing sewages, carrying down with it the suspended matter and furnishing a non-putrescible effluent. Fowler suggested to Ardern and Lockett, who were in charge of the Manchester Sewage Disposal Works, that they try experiments in aerating sewage on lines somewhat similar to what he saw in Massachusetts. As a result the *activated sludge process* is being developed.

DESCRIPTION OF ACTIVATED SLUDGE PROCESS

The first description of it was given by Ardern and Lockett[3] on April 3, 1914, at a meeting of the Manchester Section of the Society of Chemical Industry. In their first experiments Ardern and Lockett used 5-pint bottles and drew the air through the sewage by means of an ordinary filter pump. Air was drawn through the sewage until it was completely nitrified, requiring about five weeks. The supernatant liquid was drawn off and additional sewage added. This method of treatment was repeated a number of times with the retention each time of the deposited solids. As the amount of deposited matter increased the time required for each succeeding oxidation gradually diminished. Finally a well-oxidized effluent, equal to that from efficient bacterial filters, was obtained in from six to nine hours.

In their second series of experiments, reported to the Manchester Section of the Society of Chemical Industry[4] on Nov. 6, 1914, they used barrels of 50 gal. capacity and added the air through porous tile. They had tried treatment with a continuous flow of sewage without conclusive results. In later experiments they used tanks of 20,000 gal. capacity. Their results were very satis-

*A paper read at the San Francisco meeting of the American Institute of Chemical Engineers, in the Palo Alto session, on Aug. 27, 1915.

[1]Report Concerning Location of Sewer Outlets and the Discharge of Sewage into New York Harbor (1911), 64-78.
[2]Annual Report Mass. State Bd. of Health (1913), 45, 288-304.
[3]*Jour. Soc. Chem. Ind.*, vol. 33, p. 523-39.
[4]*Jour. Soc. Chem. Ind.*, vol. 33, p. 1122-4 (1914).

factory and led to additional work in England, especially at Salford, where Duckworth[5] and Melling[6] adapted scrubbing filters to the use of the activated sludge process with great success.

In August, 1914, I had the privilege of meeting Professor Fowler and of seeing the work which had been done under his direction. On returning to this country, consulting with Fowler, experiments[7] were begun with F. W. Mohlman at the University of Illinois on Nov. 2, 1914, using 3-gal. bottles. On Jan. 4, 1915, a tank 9 in. square and 4½ ft. deep was put in operation. In the bottom of this tank was placed a porous plate made of material as "Filtros,"[8] furnished by the General Filtration Company, Rochester, N. Y.

The results of our first experiments were similar to those of Ardern and Lockett. Sewage placed in the bottles or in the little tank was submitted to a current of air for a sufficient period to oxidize it completely. The oxidation is best measured by the content of ammonia, nitrate and nitrite nitrogen. Oxidation has been carried to completion five different times with practically the same results. The time required for oxidation differed, but the courses of the reaction were similar.

As an example, in one of these experiments at the beginning 35 parts per million of ammonia nitrogen were present. (See Fig. 1.) The ammonia nitrogen remained practically constant for about four days, and then quite rapidly decreased, so that at the end of about seven days it was gone. There were no nitrates nor nitrites present in the raw sewage. The nitrites increased as the ammonia decreased. Then for a few

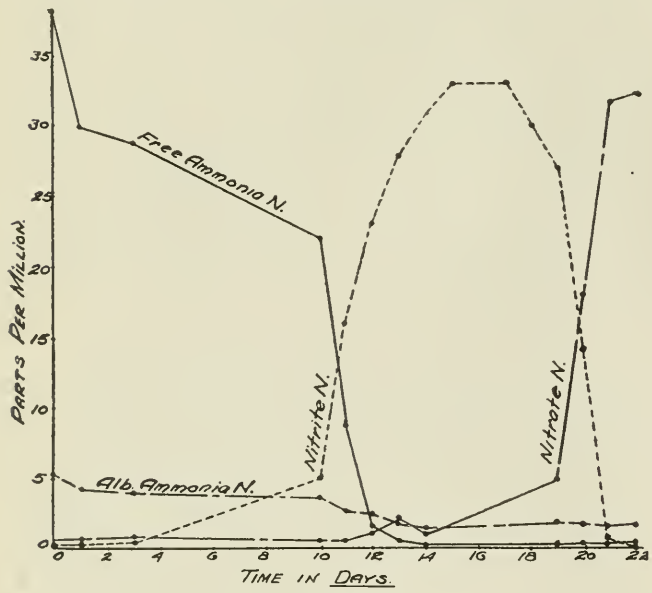


FIG. 1—NITRIFICATION OF SEWAGE—NO ACTIVATED SLUDGE PRESENT

days the nitrites remained constant and then decreased, the nitrates which were zero at the start increasing as the nitrites decreased. At the end of fifteen days nitrification was complete, the nitrite nitrogen had practically disappeared and the nitrate nitrogen had increased to about 25 parts per million. When the oxidation was complete the supernatant liquid was replaced by fresh sewage, the sludge being left. This process was repeated. With each change less time was required for oxidation, as, for example, fifteen days for the first, four days for the second, and two days for the third, and so on, until with the thirty-first treatment oxidation was complete in five hours.

With accumulation of sludge as the process is repeated the reaction follows a different course; for example (see Fig. 2), using a sewage with 27 parts per million of ammonia nitrogen, the ammonia decreases and is practically eliminated in five hours. The nitrite nitrogen never increases to any extent; the nitrate nitrogen begins to increase almost at the start, increasing as the ammonia nitrogen decreases, and reaches its maximum when the ammonia nitrogen has disappeared. It is not necessary to obtain complete nitrification to obtain a clear or stable effluent. More information must be obtained before the amount of nitrification required can be known.

The process is undoubtedly bacteriological. The sludge is very rich in bacteria, but the number in the

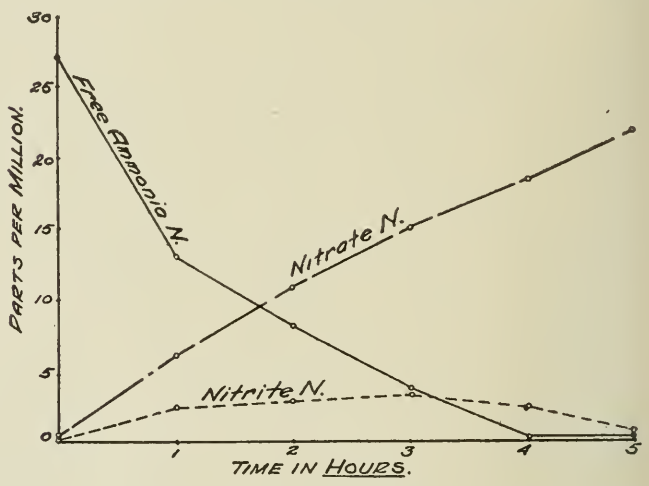


FIG. 2—NITRIFICATION OF SEWAGE—ACTIVATED SLUDGE PRESENT: 1 SLUDGE, 5 SEWAGE

effluent is comparatively small. Mr. Robbins Russell investigated the bacteriological properties of the sludge. Several species of bacteria were isolated from the sludge, including two kinds of nitrifiers and about fifteen other varieties. Experimenting with sterilized sewage it was found that the nitrifiers alone would not purify the sewage. Mixtures of the nitrifiers with the other bacteria would completely purify the sterilized sewage.

In an article which was presented before the American Chemical Society[9] mention was made of some worms which developed in the process, and which were identified by Professor Frank Smith of the Zoological Department of the University of Illinois as Aeolosoma Hemprichi. It seemed possible that these worms might play an important rôle in the purification process. Having isolated about 200 of these worms as completely as possible from the bacteria and sewage, Mr. Russell added them to sterilized ammonia broth and aerated it, obtaining practically no nitrification. The worms are, therefore, not essential and the bacteria which were isolated from the sludge did nitrify sterilized sewage.

PROPERTIES OF SLUDGE

The fresh sludge is odorless. It will putrefy if left with a large amount of water. After filter pressing it is stable. The dried sludge has an odor similar to that of fertilizers. The sludge is rich in nitrogen, 4.0 to 6.4 per cent. Its value as a fertilizer has been shown by pot cultures, made by W. D. Hatfield under the general direction of Prof. C. G. Hopkins and with the

[5] *Surveyor*, 46, 681-2 (1914).
[6] *J. Soc. Chem. Ind.* 33, 1124-30.
[7] *J. Ind. Eng. Chem.* 7, 318 (1915); *Eng. News*, 73, 647-8 (1915); *Eng. Record*, 71, 421-2 (1915); *Eng. Contrg.* 43, 310-1 (1915).
[8] Through the courtesy of the manufacturers a number of the plates were exhibited at the meeting. The plates are made of a very pure and carefully graded quartz, fused together with powdered glass.
[9] *J. Ind. Eng. Chem.*, 7, 318 (1915).

FIG. 3—POT CULTURES, WHEAT TWENTY-THREE DAYS AFTER PLANTING

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 g. dried activated sludge. No. 1 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood, and No. 1 contains no nitrogen.

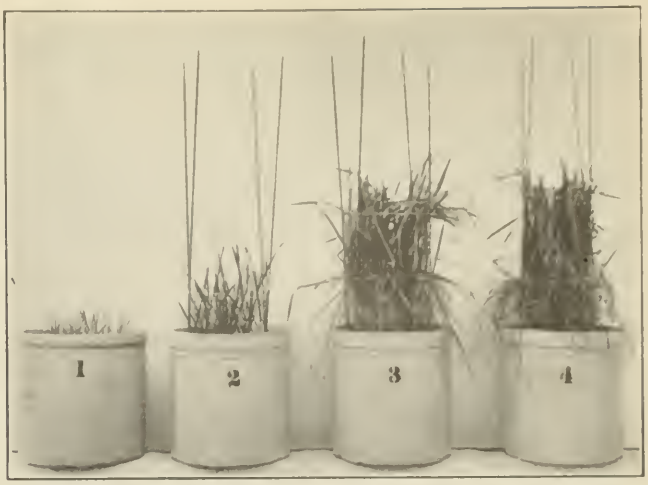


FIG. 4—POT CULTURES, WHEAT SIXTY-THREE DAYS AFTER PLANTING

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 g. dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood, and No. 1 contains no nitrogen.

assistance of Mr. J. C. Anderson of the University of Illinois. The pot cultures are made according to a standard method. Each pot contains 19,820 grams of pure white sea sand, 60 grams of dolomite, 6 grams of bone meal, and 3 grams of potassium sulphate; that is, each pot contained an equivalent of 5 tons per acre of dolomite, ½ ton of bone meal, and 500 lb. of potassium sulphate. There is in the pots all of the constituents of a plant food except nitrogen.

Pot 1 contained no nitrogen. Pot 2 contained dried blood equivalent to 120 lb. of nitrogen per acre. Pots 3 and 4 contained the equivalent of 120 lb. nitrogen, or 1 ton of sludge per acre. Thirty wheat seeds were planted in each pot. In four days the plants were up in each pot, and in ten days were 5 in. high. At the end of eighteen days each pot was thinned to fifteen of the best plants. A noticeable difference was observed after twenty-three days. (See Fig. 3.) The pots fertilized with the sludge grew very much more rapidly than any of the others. The difference at the end of nine weeks (see Fig. 4) was very marked. The differences seemed too great to be true, so another series was planted. Similar results were obtained. (See Fig. 5).

Judgment of the results of such an experiment depend on the crop. In pot No. 1 the number of heads was fourteen and the number of seeds eighty-five, corresponding to 6.2 bu. per acre. In No. 2, fertilized with dried blood, the number of heads was fifteen, seeds 189, corresponding to 13.6 bu. per acre. Dried blood is not a satisfactory fertilizer with some soils, which may account for poor results. In pots 3 and 4, fertilized with sludge, the number of heads was twenty-two and twenty-three, the number of seeds 491 and 518, corresponding to 35.9 and 37.7 bu. per acre. A very fair yield of wheat. The check experiment gave approximately the same results. The number of bushels per acre being 35.1 and 36.0.

The value of the sludge was tested with radishes and lettuce in the open field. Three plots, each 2 ft. by 3 ft., were laid out. One plot was fertilized with extracted sludge, a second with sludge and a third was not fertilized. Radishes and lettuce were planted in each. Thirty-eight days after planting the six best plants were taken from each plot. (See Fig. 6.) The difference in size was very marked. The fertilized lettuce weighed 40 per cent more than the unfertilized, and fertilized radishes weighed 150 per cent more than the unfertilized.

Both the pot cultures and the gardening experiments

FIG. 5—POT CULTURES, WHEAT SERIES 2, THIRTY-FIVE DAYS AFTER PLANTING

Each pot contains pure white sand to which the same amount of plant foods except nitrogen have been added. No. 3 contains 20 g. dried activated sludge. No. 5 contains 20 g. of dried activated sludge from which other soluble matter has been removed. No. 7 contains the nitrogen equivalent from sodium nitrate. No. 9 contains the nitrogen equivalent from ammonium sulphates. No. 11 contains the nitrogen equivalent from gluten meal. No. 13 contains the nitrogen equivalent from dried blood.

FIG. 6—GARDENING EXPERIMENTS, THIRTY-EIGHT DAYS AFTER PLANTING

Radishes. From left to right six radishes fertilized with extracted sludge, six radishes fertilized with sludge, six radishes unfertilized. Lettuce. Six heads fertilized with extracted sludge, six heads fertilized with sludge, six heads unfertilized. The fertilized lettuce weighed 40 per cent more than the unfertilized and fertilized radishes 150 per cent more than unfertilized.

show that the nitrogen in activated sludge is in a very available form, and that the sludge is valuable as a fertilizer.

APPLICATIONS OF THIS PROCESS IN AMERICA

The process is attracting a great deal of attention in America, and a very good statement[10] concerning the work being done is given in *Engineering News*, July 15. Mr. M. N. Baker has given an editorial review of the subject.

The most extensive work is being done at Milwaukee. An article by Mr. T. Chalkley Hatton[11] gives a more complete account of the Milwaukee experiments. Two tanks of 1 x 5 x 10 ft. deep and one tank 10½ x 32 x 10 ft. deep have been operated on the fill-and-draw plan, and one tank, 10½ x 32 x 10 ft. deep, is operated on the continuous plan. The Milwaukee Sewerage Commission has awarded contracts for the construction of a plant to treat 2,000,000 gal. of sewage per day by continuous flow.

At Baltimore they have been working on a small scale, but have adapted two of the new Imhoff tanks for use by this process, and it is expected that in a short time they will be using activated sludge on a large scale.

At Washington, the Hygienic Laboratory of the Public Health Service is experimenting on a small scale and is co-operating with the department at Baltimore in their experiments.

At Cleveland experiments are being carried on in the sewage experiment station. They have adapted tanks 5 x 10 and 5 ft. deep, which they used in their sewage experiments to the process, and while it has barely begun they are getting promising results. Experiments are to be carried out on a larger scale.

At Regina, Saskatchewan, experiments on a considerable scale have been carried out and their results are reported by R. O. Wynne-Roberts.[12]

At Houston, Tex., they are planning to use the process in a plant to ultimately treat the sewage from 160,000 people. They do not expect to obtain complete nitrification, as they do not believe that a completely purified effluent is necessary.

In Chicago the Sanitary District of Chicago is using tanks about 2 ft. in diameter and 8 or 10 ft. high with quite satisfactory results, using the waste from the stockyards, one of the most difficult wastes that we have to treat.

At the University of Illinois, Urbana, we are operating four tanks on the fill-and-draw plan. Each tank has an area of 10 sq. ft. and a depth of 8 ft. About 400 gal. can be added to each tank at each filling. The bottoms are one-ninth, one-third, and all (in two tanks) covered with filtros plates to try to determine the best arrangement for the diffusion of air. Of the three schemes tried one-third of the bottom with the rest slanting toward the plates seems better than the other schemes.

A study of methods of developing sludge shows that sludge can be developed from raw sewage by changing the sewage every six hours. A full description of the plant and the experiments will be given in a later article.

From 1 to 2 cu. ft. of air per gallon of sewage is needed, and the cost of the air, with electric current at 2 cents per kilowatt-hour, we estimate will be from $5 to $8 per million gallons. At Milwaukee, where they are using a little more air, they estimate the cost of the air with electric current, at 1 cent per kilowatt-hour, to be $1 per hour of aeration. If they aerate for four hours that would be $4 per million gallons for the cost of the air.

[10] *Eng. News*, 74, 164-71.
[11] *Eng. News*, 74, 134-7.
[12] *Canadian Engineer*, 29, 112-3.

This method of sewage purification is giving such satisfactory results in the purification of sewage on a small scale under summer conditions, that it will be tried on a large scale and under winter conditions, so that we ought to know by spring whether it is a success.

State Water Survey, University of Illinois,
Urbana, Ill.

Columbia Section, American Institute of Mining Engineers

The fifth annual meeting of the Columbia Section, A. I. M. E., will be held in Wallace, Idaho, Nov. 19-20, 1915. Arrangements have been made for trips to the Tamarack, Interstate, Success and other mines and to the concentrating mills of the Cœur d'Alene district. The sessions of the first day will be devoted to the reading and discussion of the following papers: "Progress in Ore-Dressing," by D. W. Buckby; "Mine Accounting," by J. E. Chapman; "Zinc Smelting and Smelter Rates," by W. E. Henry. The business session and banquet will be held on the second day. A special invitation is extended to members of the Montana Section to attend this meeting.

Equipment of Arizona Smelters

In one of the papers presented at the recent sessions of the International Engineering Congress, in San Francisco, Dr. James Douglas gave the following condensed data on the equipment of smelting plants in the State of Arizona. A notable feature is the increasing number of reverberatory furnaces and the absence of blast furnaces in the newer plants.

Copper Queen Cons. Mining Co. at Douglas, Arizona.
10 blast furnaces, 18 ft. and 20 ft. by 42 ft.
3 reverberatories, 91½ ft. by 19 ft.
7 12-ft. converters.
16 roasters.

Calumet & Arizona Mining Co. at Douglas, Arizona.
2 40-ft. blast furnaces.
4 reverberatories, 19 ft. by 100 ft.
6 stands 12-ft. upright converters of the Great Falls type.
12 roasters.

United Verde Copper Co. at Jerome, Arizona.
4 blast furnaces, 27½ ft. by 4 ft.
4 reverberatories, 100 ft. by 19 ft.
6 roasters.
5 12-ft. upright converters of Great Falls type.

Arizona Copper Co. at Clifton, Arizona.
No blast furnaces.
4 reverberatories, 19 ft. by 100 ft.
6 roasters.
6 stands 12-ft. upright converters of Great Falls type.

The American Smelting & Refining Co. at Hayden, Arizona.
No blast furnaces.
2 reverberatories, 19 ft. by 112 ft.
8 roasters.
3 converters.

Detroit Copper Mining Co. of Arizona, Morenci, Arizona.
1 large blast furnace.
4 small converters.

Old Dominion Copper Mining and Smelting Co., Globe, Arizona.
The Old Dominion Company has not yet added a reverberatory to its cupola plant, as the volume of concentrates from the small concentrator has been insufficient to economically feed one. Its plant consists of
6 cupola furnaces, of which more than 4 are seldom used.
2 12-ft. converters of Great Falls type.
one only of which is retained in blast, and it has, without relining, turning out 43,000,000 lb. of copper.

Shannon Copper Co. at Clifton, Arizona.
3 blast furnaces.
2 stands of converters.

International Smelting & Refining Co., Globe, Arizona.
(to treat the Inspiration and Miami Concentrates)
No blast furnaces.
3 reverberatories.
6 roaster furnaces.
6 converters.

Consolidated Arizona Smelting Co., Humboldt, Arizona.
(Humboldt Smelter)
2 reverberatories, 19 ft. by 60 ft. and 19 ft. by 100 ft.
1 Wedge roaster.
2 converters.

Pulverizer Mill—The Fuller-Lehigh pulverizer mill is completely described in an excellent catalog recently issued by the makers, the Lehigh Car, Wheel & Axle Works, Catasaqua, Pa. Besides this description lists are given showing parts of the various sizes and types of mills and illustrations showing installations of Fuller mills in electrically driven and line-shaft driven plants.

Thermal Principles of the Blast Furnace—II

BY J. E. JOHNSON, JR.

In the first article on the thermal principles of the blast furnace I have explained that the heat balance of the blast furnace must be considered not as one, but as two; that there are, in fact, two sets of thermal requirements, one for the preparation of the ore for its descent into the hearth, the other for the production of thoroughly reduced and melted pig iron from the ore so prepared. The present article will show how these amounts may be calculated in detail and will analyze the effect of solution on fuel consumption.

The disposition made of the two kinds of heat had seemed until recently impossible to determine, partly on account of lack of data of actual furnace operations, particularly of accurate average analyses of top gases, since a variation of a few per cent of CO_2 makes a vast difference in the heat developed. Very recently, however, two excellent sets of such data have been published, one by Mr. Walther Mathesius in his paper before the American Institute of Mining Engineers on "The Use of High Blast Heats in Mesabi Ore Practice," the other by Mr. Sidney Cornell in an article, entitled "The Heat Balance of the Blast Furnace," in METALLURGICAL AND CHEMICAL ENGINEERING for December, 1914.

In the latter the unit of weight used is the furnace charge which yielded in that case 15,260 lb. of iron, in the former the unit used is the ton of iron, but I have reduced them both to the pound basis to which the charted results of Reece's work (Table IV) are directly reducible by simply pointing off two places, it being on the basis of 100 lb. of iron.

In order to reach comparative results we must decide what heat to consider as consumed by the furnace and what as simply developed and then carried out of it. I have adopted the rule that the heat brought in plus that developed less that taken out as sensible heat should be charged to the furnace as consumed.

A curious oversight has crept into the work of both Messrs. Mathesius and Cornell which it has been necessary to correct. They have given the furnace credit for the heat of dissociation of the moisture in the blast, but they have ignored the much larger quantity of heat required for the dissociation of moisture of the charge in the upper portion of the furnace.

Mr. Mathesius takes cognizance of 69 lb. of moisture dissociated per ton of iron from the blast, but the analysis he gives of top gas shows that 240 lb. of water in all are dissociated, there being 27.3 lb. of hydrogen per ton of iron in the top gases. This arises, as pointed out by A. N. Diehl in his paper "Data Pertaining to Gas Cleaning," from the dissociation of the moisture in the ore in the upper part of the furnace. It seems at first sight surprising that this should take place, but it is not when we consider that CO burnt to CO_2 develops 7650 B.t.u. per pound of oxygen, while H_2O to $H_2 + O$ absorbs only 6530 B.t.u. per pound of oxygen.

The heat necessary for this latter reaction has been entirely overlooked by both these writers, with the result that in one set of data the "loss by radiation and unaccounted for" is much larger than it should be. On the other hand, the oxygen arising from this reaction is similarly ignored and the gas analysis given does not account for all the oxygen which must have been present in the top gases.

Calculations based on operating data give us the only means we have of investigating what occurs inside the furnace, and the method of making these is of much importance to show this and simultaneously to obtain the correct figures for the heat developed. We may, therefore, give the calculations based on the excellent data of Mr. Mathesius.

His "Calculations of Operating Results," which contain the data we need, are reproduced here.

CALCULATION OF OPERATING DATA

Analysis of Top Gases

		By Volume	By Weight
(1)	CO_2	14.9	22.3
	CO	23.5	22.4
	H_2	4.1	0.3
	CH_4	0.2	0.1
	N_2	57.3	54.9

On the basis of above data 1 ton of this gas contains:

(2) $$\frac{22.3 \times 3}{100 \times 11} = 0.0608 \text{ ton of carbon as } CO_2$$

and $$\frac{22.4 \times 3}{100 \times 7} = 0.0960 \text{ ton of carbon as CO}$$

This carbon originates from:

(*a*) The carbon charged, minus the amount of carbon transferred to the iron and the amount carried off with the flue dust.

(*b*) The CO_2 content of the raw materials.

These items are calculated below:

(*a*) The total amount of coke charged during the period under consideration was

(3) 13,006 tons,

which analyzed:

(4)	Fixed Carbon	Ash	S	P	Volatile Matter
	89.00	9.40	0.59	0.008	1.35 per cent

(5) The coke as weighed averaged 2.30 per cent moisture, making the weight of dry coke charged:

(6) 12,707 tons.

The amount of fixed carbon charged is thus:

(7) $$\frac{12{,}707 \times 89.00}{100} = 11{,}310 \text{ tons.}$$

From this total is to be deducted:

(*a*1) The carbon carried off with the iron, which is calculated as follows:

(8) The carbon content of the metal was 4.20 per cent and

(9) 17,146 tons of iron were produced, besides

(10) 173 tons of scrap (ladle skullings and pig-machine scrap); therefore

(11) 17,319 tons of iron (17,146 + 173) carried off

(12) $$\frac{4.20 \times 17{,}319}{100} = 727 \text{ tons of carbon.}$$

Besides the regular burden, the furnace remelted 276 tons of scrap iron, which contained:

(13) $$\frac{276 \times 4.20}{100} = 11 \text{ tons of carbon.}$$

Therefore the net amount of coke carbon carried off with the metallic product is:

(14) 727 — 11 = 716 tons.

(*a*2) During the month 628 tons of flue dust were taken out of the dust catcher of the furnace. Assuming that the gas carried over an additional 10 per cent of this beyond the dust catcher, the total amount of flue dust produced by the furnace was,

(15) 691 tons.

(16) Since the average carbon content of the flue dust was 8.25 per cent, the amount of carbon carried from the furnace with the dust amounted to

(17) $$\frac{8.25 \times 691}{100} = 57 \text{ tons.}$$

Consequently the net amount of carbon gasified in the furnace is:

(18) 11,310 — (716 + 57) = 10,537 tons.

(*b*) The only burden constituent containing CO_2

(19) in larger quantities was limestone, of which 6154 tons were charged. It averaged 43.1 per cent CO_2, making the amount of CO_2 charged with the lime-

(20) stone $\frac{43.1 \times 6154}{100} = 2652$ tons which is equivalent

(21) to $\frac{2652 \times 12}{44} = 723$ tons of carbon.

(22) The CO_2 content of the other burden constituents (ore, scale and cinder) averaged about 1 per cent, giving off an additional

(23) $\frac{31,372 \times 1}{100} = 314$ tons CO_2, which is equivalent to

(24) $\frac{314 \times 12}{44} = 86$ tons of carbon.

The total amount of carbon which escaped from the furnace during the month in the shape of CO_2 and CO is, therefore (see 18, 21 and 24),

(25) $10,537 + 723 + 86 = 11,346$ tons

Each ton of the top gases containing 0.568 ton (see 2) of carbon, the total weight of the dry top gases for the month is:

(26) $\frac{11,346}{0.1568} = 72,360$ tons.

The total weight of water, which was charged into the furnace with the ore, coke and limestone, and which subsequently had to be evaporated, leaving the furnace together with the top gases, was, according to the analysis of the burden constituents,

(27) 4665 tons

The nitrogen content of the dry top gases (see 1) originating exclusively from the blast, and the nitrogen content of the air being known, the weight of the dry air which entered into the furnace through the tuyeres can be calculated as follows:

(28) $\frac{72,360 \times 54.9}{77} = 51,592$ tons.

(29) The average moisture of the atmosphere was 5.49 grains per cubic foot at 70 deg. Fahr., making the weight of natural air blown into the tuyeres,

(30) $51,592 + 539 = 52,131$ tons.

The slag volume according to the daily burden

(31) calculations averaged 45.5 per cent, making the

(32) total amount of slag produced, 7811 tons.

The weight of materials passed through the furnace was as follows:

(33)

Material	Total Tons	Per Ton of Product Including Scrap Produced	
		Tons	Pounds
Burden	31,645	1.827	4,093
Limestone	6,154	0.355	795
Coke	13,006	0.751	1,682
Product (including scrap)	17,319		
Slag	7,811	0.451	1,010
Flue dust	691	0.040	89
Blast (excluding moisture)	51,592	2.979	6,673
Moisture in blast	539	0.031	69
Top gas (excluding moisture)	72,360	4.173	9,359
Moisture in gas	4,665	0.269	603

According to the average monthly analysis the product consisted of,

(34)

C.	Si.	Sul.	Phos.	Mn.	Fe.
4.20	1.35	0.032	0.071	0.74	93.61 per cent

The iron content originated from the following amounts of burden constituents:

(35)

Material	Group 1	Group 5	Pewabic Genoa	Pit Cinder	Steel Scale	Scrap	Coke	Total
Iron, per cent	52.00	49.00	35.00	50.00	66.00	75.00	0.80	
Stage of oxidation	Fe_2O_3	Fe_2O_3	Fe_3O_4	Fe_3O_4	Fe_3O_4	Fe	Fe	
Pounds per ton of product	2,819	755	219	58	207	36	1,682	
Pounds minus 1 per cent. loss	2,791	748	217	57	205	35	1,665	
Pounds iron per ton of product	1,451	366	76	29	136	26	13	2,097

Consequently the iron content of 1 ton of product originated from the following stages of oxidation:

(36)

Fe	Fe_3O_4	Fe_2O_3
39	165	1,893 Pounds

(37) In the same manner it results that 1 ton of product contained 0.74 per cent, or 16.6 lb., of manganese; 16.3 lb. of which have been reduced from MnO, while 0.3 lb. were contained in the scrap charged.

(38) The phosphorus of the product amounts to 1.6 lb. per ton and has been reduced practically all from P_2O_5.

(39) The 1.35 per cent of silicon is equivalent to 30.2 lb. per ton, of which 29.7 lb. were reduced from SiO_2, while 0.5 lb. were contained in the scrap charged.

HEAT BALANCE

(a) *Heat Generation*

The total weight of carbon contained as CO_2 in the top gases per ton of product is (see 2 and 33):

(40) $0.0608 \times 9359 = 569.0$ lb.

The weight of carbon per ton of product, equivalent to the amount of CO_2 originating from the limestone and burden and contained in the top gases is (see 21, 24 and 33):

(41) $\frac{809 \times 2240}{17,319} = 104.6$ lb.

Deducting item (41) from (40) gives the weight of coke carbon burned to CO_2 per ton of product:

(42) $569.0 - 104.6 = 464.4$ lb.

One pound of carbon through combustion to CO_2

(43) generates 14,543 B.t.u.; the above 464.4 lb. gener-

(44) ated, therefore, 6,754,000 B.t.u.

The amount of carbon per ton of product burned

(45) to CO is (see 2 and 33): $0.0960 \times 9359 = 898.5$ lb.

One pound of carbon through combustion to CO

(46) generating 4446 B.t.u., the above 898.5 lb. generated

(47) 3,995,000 B.t.u.

(48) The specific heat of the air blast being 0.248 and

(49) the average hot-blast temperature 1248 deg. Fahr., the heat brought into the furnace with the blast

(50) (see 33) per ton of product is: $1243 \times 0.248 \times 6.673 = 2,057,000$ B.t.u.

In the same manner the amount of heat brought into the furnace per ton of product with the moisture (specific heat, 0.49) content of the blast (see 33) is:

(51) $1243 \times 0.49 \times 69 = 42,000$ B.t.u.

(b) *Heat Consumption*

The following data were used in these calculations:

(52)

	B.t.u.
Heat required to reduce Fe_2O_3 to 1 lb. of Fe	3,240
Heat required to reduce Fe_3O_4 to 1 lb. of Fe	2,970
Heat required to reduce MnO to 1 lb. of Mn	2,970
Heat required to reduce SiO_2 to 1 lb. of Si	14,090
Heat required to reduce P_2O_5 to 1 lb. of P	10,620

The reduction of 1 ton of product therefore requires the following heat (see 34, 36, 37 and 38):

(53)

		B.t.u.
1893	lb. of Fe from Fe_2O_3	6,133,300
165	lb. of Fe from Fe_3O_4	490,000
16.3	lb. of Mn from MnO	48,400
1.	lb. of P from P_2O_5	17,000
29.1	lb. of Si from SiO_2	418,500
	Total	7,107,200

The weight of CO_2 produced by the calcination of carbonates per ton of product is, according to (20, 23 and 33):

(54) $\frac{(2652 + 314) \times 2240}{17,319} = 384$ lb.

practically all of which was contained in the burden in the form of $CaCO_3$. The heat necessary to de-

(55) compose $CaCO_3$ into CaO and CO_2 is 1830 B.t.u. per pound of CO_2. The driving off of above 384 lb. required.

(56) $1830 \times 384 = 702{,}000$ B.t.u.

The amount of heat carried from the furnace by the slag and iron was not determined. The figures used represent the average results of former tests under similar conditions. According to these the heat carried off by 1 lb. of iron amounted to

(57) 510 B.t.u. and per pound of slag to 900 B.t.u.

The heat carried off per ton of product with the iron amounts to

(58) $510 \times 2240 = 1{,}142{,}500$ B.t.u.

and with the slag

(59) $900 \times 1010 = 909{,}000$ B.t.u.

The dissociation of the moisture as carried into the furnace with the blast requires, per pound of

(60) water vapor, 5760 B.t.u.; per ton of product, the heat required for this reaction was (see 33):

(61) $69 \times 5760 = 397{,}000$ B.t.u.

The dry top gases carried off the following amount of heat per ton of product. (The average top temperature was 325 deg. Fahr., (see 1) for the gas analysis and (33) for the weight of gas.)

	Gas analysis	× Weight of gas	× Top temperature	× Spec. Heat	= B.t.u.
CO_2	0.223	9,359	325	0.2169	147,100
CO	0.224	9,359	325	0.2426	165,300
(62) H_2	0.003	9,359	325	3.4090	31,100
CH_4	0.001	9,359	325	0.5930	1,800
N_2	0.549	9,359	325	0.2438	407,100
Total					752,400

The moisture carried out by the top gases entered the furnace at a temperature of 70 deg. Fahr., i.e., with a heat content (see 33) per ton of product of

(63) $(70 - 32) \times 603 = 22{,}900$ B.t.u.

Since the moisture was heated in the furnace to 212 deg. Fahr., and evaporated, and the resulting steam superheated to 325 deg. Fahr., the heating of the water required

(64) $(212 - 32) \times 603 - 22{,}900 = 85{,}600$ B.t.u.

The evaporation required

(65) $964.8 \times 603 = 581{,}800$ B.t.u.

The superheating required

(66) $0.48 \times (325 - 212) \times 603 = 32{,}700$ B.t.u.

Therefore the total heat carried off with the top gases per ton of product amounts to

B.t.u.	
85,600	(see 64)
581,800	(see 65)
32,700	(see 66)
(67) 700,100	

[End of quotation from Mathesius.]

In the following calculation the letter M followed by a number indicates the item bearing that number in the quotation from Mathesius.

Let us start with the fundamental fact that carbon in the gaseous condition whether CO_2, CO or CH_4 has a volume of 29.85 cu. ft. per pound of carbon.

The total carbon gasified (M25) is 11,346 tons per month and the iron produced (M33) is 17,319 tons per month, or 0.655 lb. C per pound of iron. Therefore the carbon gas per pound of iron is $0.655 \times 29.85 = 19.57$ cu. ft. The carbon gas in percentage of total (M1) is CO_2, 14.9 per cent, CO 23.5 per cent or 38.4 per cent total. (We can disregard the CH_4 because no account is taken of the volatile matter of the coke, which undoubtedly contains some carbon). 19.57 being the volume of carbon in cubic feet and 38.4 in percentage, the total volume of gas is $\frac{19.57}{0.384}$ or 50.9 cu. ft. per pound of iron. The nitrogen is (M1) 57.3 per cent of this or 29.2 cu. ft. and as all this comes from the blast of which it constitutes 79.3 per cent, the blast blown must have been 36.8 cu. ft. per pound of iron. This weighs 0.0807 per cubic foot or 2.97 lb. of which 23 per cent by weight is oxygen or 0.683 lb. The oxygen from the charge may be obtained most easily from M53 and 54.

1893	lb.	Fe as Fe_2O_3 carries	$\frac{3}{7} \times 1893$	= 810	lb. O.
165	lb.	Fe as Fe_3O_4 carries	$\frac{64}{168} \times 165$	= 62 9	lb. O.
16.3	lb.	Mn as MnO carries	$\frac{16}{55} \times 16\ 3$	= 4 8	lb. O.
1 6	lb.	P as P_2O_5 carries	$\frac{80}{62} \times 1\ 6$	= 2 1	lb. O.
29 7	lb.	Si as SiO_2 carries	$\frac{32}{28} \times 29\ 7$	= 33 9	lb. O.
				913 7	

From (M54) we find 384 lb. of CO_2 carrying $32 \div 44 \times 384 = 279$ lb. per ton, a total from these sources of $913.7 + 279 = 1192.7$ lb. per ton or 0.5325 lb. per pound of iron. To this must be added the oxygen of the blast 0.683 lb.

The moisture in the blast is dissociated in the hearth and the oxygen is added to that from the other sources and Mr. Mathesius has added this, which is quite proper as far as it goes, but it takes no account of the oxygen which comes from the dissociation of the water in the *upper* portion of the furnace. The moisture in the blast is 69 lb. per ton of which one-ninth or 7.68 lb. per ton or 0.0034 lb. per pound of iron is hydrogen. The hydrogen in the top gas is, however, 4.1 per cent by volume, while the carbon gas is 38.4 per cent and 19.57 cu. ft. therefore the volume of hydrogen is $4.1 \div 38.4 \times 19.57 = 2.09$ cu. ft. or $2.09 \div 178.23 = 0.0117$ lb. or over *three times* as much as the moisture of the blast accounts for. This hydrogen can only come from one source, the dissociation of water. The volatile matter of the coke would not account for all of it if the latter were *all* hydrogen, and such analyses as we have show it to contain little or none of that gas. We must, therefore, take account of the heat absorbed by this reaction and of the oxygen as well as the hydrogen produced by it. This oxygen is obviously $0.0117 \times 8 = 0.0936$ lb. per pound of iron. We have then finally

Oxygen from oxides of charge	0.407
Oxygen from carbonates of charge	0.124
Oxygen from blast	0.683
Oxygen from dissociation of water of charge	0.0940
	1.3081

Oxygen required for oxydizing 0.655 C to CO is $0.655 \times 1\ 1/3 = 0.874$ lb. $1.308 - 0.874 = 0.434$ lb. O left to oxydize CO to CO_2 which suffices to convert 0.326 lb. of C from CO to CO_2. Of this C $12 \div 44 \times 384 \div 2240 = 0.047$ lb. came from the carbonates as CO_2 and therefore generates no heat. We have therefore $0.326 - 0.047 = 0.279$ lb. C burnt to CO_2 and $0.655 - 0.326 = 0.329$ C burnt to CO.

0.279 C to CO_2 at 14,750 B.t.u	= 4115
0.32 C to CO at 4375 B.t.u	= 1437
Brought in by blast and moisture (M) $\frac{2{,}099{,}000}{2240}$	= 937
	6489 B.t.u. per lb. of iron

The heat taken out may be considered in various ways: Cornell considers all the heat taken out whether sensible, latent or potential as having been developed in the furnace and then abstracted, while Mathesius considers the latent heat of evaporating the water of the charge as generated and taken out but not the heat of the unburned gases. On the basis previously adopted of considering only sensible heat as taken out I consider that

the latent heat of the water of the charge represents part of the heat consumed in the furnace which is what we are trying to determine. On the other hand the heat which the gas can develop by further combustion obviously plays no part in the operation and should not be considered. On this basis the rule is that sensible heat taken out should be credited to the furnace, but not latent heat, in order to determine its actual heat consumption.

For convenience the sensible heat of the water vapor is taken as starting a 0 deg. although, of course, it is not actually evaporated until many degrees above that point. The error so produced is immaterial especially as there are necessarily many other errors of greater extent due to uncertainties in our data.

The heat removed on this basis is then found as follows:

The specific heat of furnace gas is ordinarily 0.02 B.t.u. per cubic foot, but in this case, on account of the large percentage of CO_2, it is about 0.0205. The volume of the top gases is 50.9, the top temperature is 325 deg., and the heat removed per pound of iron by dry gas is $50.9 \times 325 \times 0.0205 = 340$ B.t.u., and the sensible heat of the water vapor is 0.269 lb. per pound of iron $\times$ 0.46 $\times$ 325 = 40 B.t.u. a total deduction of 380 B.t.u.

The net heat consumed, therefore, is 6489 — 380 = 6109, say, 6110 B.t.u. per pound.

To this we should add the heat brought in by the raw materials at, say, 60 deg. Their weight is about 3½ lb. per pound of iron, and their specific heat about 0.18, so the heat introduced in this way is about 35 B.t.u., which is not worth bothering with.

Before proceeding to the discussion of heat utilization we may compare the analysis derived from these figures with those given in the paper. The total carbon gas remains the same as does its percentage of the whole; we have therefore only to divide the total percentage of carbon gas 38.4 per cent in the ratio of 0.326 and 0.329, which gives 19.2 per cent CO_2 and 19.3 per cent CO, as against the initial figures given by Mathesius of 14.9 and 23.5. In the data given by Cornell there are included an estimate and an actual gas analysis, and the CO_2 in the estimate is 12.50 per cent and in the test 13.06 per cent, while my estimate made as above is 14.2 per cent.

We have therefore a considerable discrepancy which we can only account for in one of two ways:

A. The analyses are wrong as to the subdivision of the carbon gas, due to some error of not absorbing the CO_2 completely before proceding to determine the CO or the like.

B. The hydrogen does not arise from the dissociation of water, but is driven off as such from some portion of the charge, presumably the volatile matter of the coke, which, as before stated, is hardly possible.

Fortunately for the correctness of our estimate of heat development, this uncertainty makes very little difference, strange as this may seem, for if the hydrogen *does* come from the dissociation of water we obtain the corresponding oxygen which must oxidize the carbon to the extent shown with the corresponding development of heat, six-sevenths of which must be applied to the dissociation of the water. On the other hand, if the hydrogen does not come from this source, this heat of dissociation is not required and the oxygen resulting therefrom is not produced to cause the oxidation of the carbon to the corresponding extent.

We find then that the total heat consumption per pound of iron in the three cases is as follows:

Mathesius	Cornell	Reece
6110	6860	6440

Reece's furnace had a considerably smaller output than the others; in fact, not much over half, while the external dimensions of the shell in his case were not very much smaller than theirs, so that the radiation loss is probably considerably larger per pound of iron. On the other hand, no hydrogen is given in his gas analysis, and if this were correct (which the use of a large proportion of hard ore in his practice renders probable), we have a considerably larger consumption of heat per pound of iron than in Mathesius' case.

The total heat consumed in the Cornell example is greater than in Mathesius' by about 10 per cent, of which a part is to be accounted for by the evaporation of more water and the dissociation of more coke in the shaft, but proper allowance for these items still leaves a discrepancy of 7 or 8 per cent for which we are frankly unable to account except on the basis of errors in the gas analyses which underlie the whole structure and which are easily possible.

It should be noted that this variation of 8 per cent corresponds with one of nearly 40 per cent in fuel consumed in the two cases, and is in a broad way a confirmation of the fact that the heat consumption of furnaces working under very different conditions varies but little, as compared with variations in the fuel consumption.

It is a matter of interest also that the heat consumption in the cases of Reece and Cornell are almost identical if we omit from the latter the heat charged to it for the dissociation of water in the shaft, for which nothing has been charged in the case of Reece for the reasons given.

As to the radiation loss per square foot of furnace surface at different temperatures we know little or nothing; the difficulties in the way of investigation are great, and as we do not know how to improve our construction from the point of view of reducing radiation losses it has not seemed worth while to investigate them, and it has apparently never been done thoroughly.

It is well to point out that in those coke furnaces in which the deficiency of heat is in the hearth—that is, those which need more blast heat than they can obtain—the heat carried off from the hearth and bosh is the only portion whose loss affects the economy of the furnace, because it represents a loss of that portion which is already deficient, whereas any heat lost by radiation from the upper part of the stack represents only the loss of a surplus which would pass off as additional sensible heat in the gas if it were not lost by radiation. One proof of this is the fact that at a number of plants the stock going into the top of the furnace is thoroughly watered down to reduce the flue dust losses, and in some cases the top temperature is frankly controlled by the amount of water used. This water has all to be evaporated in the upper regions of the furnace, which requires a great quantity of heat; but no additional fuel is charged for the purpose, merely the sensible heat in the top gases is reduced.

This condition is so familiar to coke furnace operators that it is hard for them to realize that the opposite condition can ever prevail and that the economy of the charcoal furnace is at least sometimes limited by the heat developed in the shaft. But no one who considers the results of the calculations and experiment given above need ever feel any doubt of this.

Since this was written I have been told by one of the best furnacemen in the country that when the thin-lined furnace was used the cooling of the top was so considerable that the wetting of the ore to keep down flue dust had to be discontinued as it reduced the economy of the furnace. This would seem to be a direct confirmation of my results with charcoal.

We find here a smaller development of hearth heat per

pound of iron in the more economical furnace than in the less economical exactly as we found in a considerably greater degree in the charcoal furnace with wet and with dry ore, for while the dry ore figures were theoretical when made, their results were so remarkably confirmed by practice as to give them complete validity.

We have practically proven in the case of the charcoal furnace that the surplus hearth heat was utilized for relatively low-temperature operations; we shall presently see that the same is almost certainly true in the case of the coke furnace having the excess of hearth heat.

The development of hearth heat in the three cases is obtained from the actual carbon burnt in the hearth multiplied by the heat per pound of coke for the given conditions taken from chart I (page 720 of issue of Oct. 15) and divided by 0.85, the chart being for 0.85 carbon burnt.

The carbon burnt at the tuyeres is simply three-fourths the weight of the oxygen of the blast dry plus that of its contained moisture. We omit that reduced from the Si, Mn, and P, which enter the iron, although these are admittedly reduced only with incandescent carbon in the bosh because the reduction of these does not generate but absorbs heat.

The results are as follows:

Mathesius

$$\frac{0.512}{0.85} \times 1670 = 1005$$

Cornell

$$\frac{0.78}{0.85} \times 1360 = 1250$$

Reece

$$\frac{0.57}{0.85} \times 1740 = 1170$$

It will, I think, be conceded that these show a very fair agreement, especially as the slag volume in the data by Mathesius was exceedingly small.

Turning now to the method by which the hearth heat is developed we find that practically 50 per cent more carbon is burnt in the hearth in No. 2 (Cornell) than in No. 1 (Mathesius), but that only 15 per cent more hearth heat is developed by it, and the reasonable assumption is that if No. 2 had been given enough blast heat to increase the hearth heat per pound of coke to that of No. 1, *and if the distribution of the charge had been as good,* so that the furnace would take advantage of the increase, it would have done as good work as No. 1.

The clause in italics is very important. Cases are numerous enough in which a change in the stock distribution had produced an improvement of 30 per cent in fuel economy. The exact cause of the excess fuel required with bad distribution we do not know, and undoubtedly it varies in different cases, but broadly we may be sure that generally, if not always, it is *the result of having to do work in the hearth that should have been done in the shaft,* and this must necessitate the development of a surplus of hearth heat, precisely as it did at the charcoal furnace above cited, though in that case this condition was not due to bad filling.

It would seem well worth while in cases where the fuel economy is poor to make a brief analysis of the conditions and determine the amount of hearth heat developed per pound of iron. If it exceeds 1100 B.t.u. when making, say, 1200 lb. slag per ton of iron it is more than likely that the cause will be found in bad filling. In one case in my own experience the removal by better filling, without any other change whatever, of a cold core in the center of the furnace which was not properly heated and reduced by the gases in their ascent, resulted in a decrease of fuel consumption of 20 per cent and an increase in tonnage of 25 per cent.

In order to analyze the consumption of heat in detail in both hearth and shaft, let us assume that under average conditions the total heat consumed is 6500 B.t.u., and that of this the hearth heat is 1100 B.t.u., then the net heat used in the shaft is 5400 B.t.u. Let us assume that the slag volume is 1120 lb. per ton of iron (half the weight of the iron), and that the limestone charged is 1000 lb. per ton.

Our fundamental "second law" states that the heat above the critical temperature is supplied by the hearth heat, and the obvious corollary follows that the heat required below that temperature is derived from the shaft heat.

With this foundation we can make a subdivision of the gross heat consumption by remembering that only those portions of the charge which are discharged from the shaft down into the bosh take out any heat except that which passes out with the top gases, the volatile elements of the charge are heated to various temperatures in the shaft before they are detached from the non-volatile portion of the charge with which they enter, but the heat so absorbed is all given back to the charge again when they are ascending as a part of the gas column, excepting, of course, that heat which they take out as part of the top gas.

In other words, we have only to consider as credits to the shaft heat amounts which it imparts to the iron and the slag-forming materials in raising them to the critical temperature before delivering them into the bosh, and may disregard the temperature to which their gaseous components are heated when the latter are driven off, because the sensible heat so absorbed is restored to the stock column.

In considering the heat absorbed by the chemical reactions which take place in the shaft we do not need to consider the complex steps through which they pass, but only the final result, and from this point of view they are few and simple; the reduction of the iron ore, the decarbonation of the stone, the decomposition of the water vapor. In addition we have to evaporate the water of the charge and provide for the radiation loss. The shaft must supply the heat to raise to the critical temperature that portion of the coke which is burnt in the hearth, but the shaft recovers all this heat exactly as it does that expended on the volatile components of the charge. The quantities of heat required for these purposes are as follows:

Reduction of the Fe counting 95 per cent Fe in iron	2970
Decarbonation of stone	405
Heating slag forming materials to critical temperature	300
Heating Fe to critical temperature	480
Heating carbon in iron to critical temperature	45
Decomposition 0.1 lb. of H_2O from charge	580
Radiation deduced from Cornell and Mathesius	440
Evaporate moisture of charge (¼ lb.)	280
Total consumption in shaft	5500

But our original figures based in practice were 6400 total and 1100 hearth heat leaving 5300 shaft heat, an amount considerably below the actual requirements as above given.

In order to find the discrepancy let us consider next the utilization of the hearth heat. This is expended in reducing the silicon, in imparting to the iron and slag that portion of their total heat not imparted in the shaft, including the latent heat of fusion, supplying the heat lost by cooling water, radiation, and conduction through the bottom.

We know from Cornell's data the amount of the first loss 170 B.t.u. per pound and I have assumed that the other two would equal this amount which is probably a liberal assumption. I have assumed the silicon to be 1½ per cent and assumed the phosphorus and manganese to be included in this.

No attention is paid to the heat of formation of the slag and the carbide of iron since both those reactions *give out* heat in small quantities instead of absorbing it.

We have then the following consumption of heat in the hearth:

Reduction of silicon	180
Ht. of slag not imparted in shaft (900–600) ×½	150
Ht. of iron not imparted in shaft (600–480)	120
Cooling water	170
Radiation and conduction through bottom	170
	790

No allowance is made for the heat required to decompose the moisture of the blast because that has been taken care of by deducting it from the gross hearth heat.

Adding this figure to 5500 consumed in the shaft we have 6290 which is a very satisfactory check in the totals based in practice, but the distribution is obviously erroneous; we utilize in the shaft more than we produce there and in the hearth less.

Going over the matter carefully we see that the error can lie only in one place. We have assumed that *all* the reduction of iron was done in the shaft and none in the bosh, an assumption which, as we shall later see, is contrary to the observed facts of practice and to the indication of the equilibrium diagram in the last chapter which shows that the final traces of oxygen are only removed from iron oxide in an atmosphere almost free from CO_2 and at a very high temperature; conditions which are only obtained in the hearth.

We see, therefore, that a considerable percentage of the oxygen of the ore is only removed in the bosh of the furnace and from the consumption of hearth heat and the figures given above we can fairly estimate how much.

The data concerning the hearth heat are the most accurate, for the difference, which is a measure of the correction to be made, depends on the smaller number of items and the best established data.

The 790 B.t.u. accounted for, fall short of the 1100 we know to be consumed by 310 B.t.u., and as the total heat of reduction of the ore is 2970 B.t.u., this constitutes 10 per cent of the total, and we can thus feel reasonably well assured that under such conditions 10 per cent of the oxygen of the ore is removed in the bosh. This 300 B.t.u. subtracted from the original figure of 5500 consumed in the shaft leaves 5200 which is at least as good a check with the 5300 based on practice as we have any right to expect.

The high figure used for the total heat of slag is taken from the best sources obtainable and enables us to account for the facts of practice in regard to the effect of increased slag volume on coke consumption, something it is not possible to do in any other way. The heat imparted to the slag-forming materials up to the critical temperature as given in the table, 600 B.t.u., is obtained by adding the heats of the principal ingredients SiO_2, CaO, Al_2O_3, as taken from Richards' data, and is therefore fairly accurate. Deducting this from the total heat of the slag 900 we obtain a difference of 300 B.t.u., which must be imparted in the hearth by the hearth heat. The quantity of the latter per pound of coke charged (not that burned in the hearth only) is in ordinary practice about 1100 B.t.u. so that nearly 0.3 lb. of coke should be required per pound of slag. The figure commonly used is 0.25 lb., but my observation of practice in different districts where very different quantities of slag per ton of iron are made, leads me to believe that this figure is really about 0.33 lb. This is in good agreement with the figure just deduced on the basis of the critical temperature theory, but can not be squared with any other theory by any possibility. For instance, we see that the combustion of a pound of coke develops altogether under such conditions as we have been discussing about 6500 to 9000 B.t.u., taking even the smaller figure and the same high figure for the total heat of slag 900 B.t.u., 0.14 lb. of coke would be required per pound of slag, which has no relation whatever with practice.

I call particular attention to this in order to reiterate once more that the basis in which the critical temperature rests is not its reasonableness or agreement with accepted principle in other sciences but that it accounts *quantitatively* for the facts of practice, something which no other theory hitherto proposed can even attempt to do.

The shaft heat has so far been found merely by difference, subtracting from the total the hearth heat which we can calculate quite accurately and whose quantity so calculated checks well with fuel consumption over a wide range of practice, so that a number of furnacemen have come to have much confidence in the results so obtained. But while this is a small fraction of the total heat, to obtain the shaft heat merely by subtracting this small figure from the large one of total heat developed does not seem very convincing. We shall be able to show that the heat consumed in the shaft checks well with that imparted to that region; for this purpose we can use the results of calculations made for showing the results of solution loss which are given later on in this article.

There it will be seen that the heat developed and that brought into the shaft by the hot gases from the hearth supply enough for the requirements of the shaft with sufficient left over to heat the top gases to the temperature at which they are actually discharged in practice for those conditions. The radiation loss may have been assumed a little higher than it should and there are undoubtedly minor errors of constants used and assumptions made but it seems inconceivable that so involved a series of calculations could be made on the basis of authentic data and check so accurately as these do with themselves and with the conditions of practice unless they were substantially correct. Granting this we may surely say that here is a confirmation of the two-fold thermal balance of the furnace which cannot be denied since we see not only that the total heat must equal a certain quantity but that a certain portion cannot possibly be applied except above that temperature: also that the two quantities bear a definite ratio to each other depending upon the conditions of the operation.

The Determination of the Critical Temperature

The early work done for this purpose has been described in the quotation in the early part of this chapter and the critical temperature used in the coke-furnace calculations of this chapter is taken at 2750 deg., the same as the figure used for the early work, not for the sake of consistency but because the considerable amount of work done since seems to indicate that for the conditions of ordinary coke practice that figure is approximately correct.

In a valuable paper by F. E. Bachman before the American Iron & Steel Institute in October, 1914, he gives the results of pyrometric observations made by an expert from the Bureau of Standards which agree better than could have been expected with this figure taken as representing average condition of coke practice.

It is greatly to be hoped that more work will be done along this line, particularly on furnaces working under varying conditions, those making ferro-manganese, ferro-silicon and the like, as well as furnaces in different varieties of coke practice and in charcoal practice, both cold and warm blast.

When this is done we may have more correct figures for the various kinds of practice, but in the mean time 2750 deg. for most coke furnaces seems to be reasonably accurate, though on some rather lean slags the critical temperature is probably as much as 100 deg. lower.

(To be concluded.)

Solution of Smoke, Fume and Dust Problems by Electrical Precipitation*

BY LINN BRADLEY

A statement that the earth's atmosphere contains a practically unlimited supply of materials highly valued by civilized man probably would bring to mind the fact that nitrogen compounds are being extracted from the air and used as fertilizers, or perhaps in connection with the manufacture of explosives. On further reflection one might recall the publicity which has been given to the desirability of recovering certain values, among them ammonium sulphate, from the gases arising from bee-hive coke ovens. This is all very commendable, and more serious attention should be given to such recoveries.

But there are also being discharged into the atmosphere regularly many other materials, the aggregate value of which amounts to many thousands of dollars. An attempt will be made to give an outline of some of these latter problems in such a way as to promote and stimulate interest in them.

This is another field in which the recovery of valuable by-products already reflects credit upon the scientific achievements of the technical men of our country. It is indeed gratifying that in the application of electricity to the solution of such problems this country far outranks any other, a Californian, Dr. Frederick G. Cottrell, having done more to advance both the science and the art than any other individual. This special field of technical industry will be described more fully toward the end of this paper.

The terms "smoke problem," "dust problem," "fume problem" have different meanings to residents of various localities. For instance, "dust problem" has one meaning to the superintendent of a calcium carbide plant, another meaning to the foreman of an iron blast furnace, and still another to a resident of a California desert town. Each of these three little appreciates the other's problem and what it means to him.

"Fume problems" cover a great range, from garbage reduction works to sulphuric acid factories, including silver and gold refineries en route.

Even "smoke problem" is not a specific term always meaning the same thing, because some people are inclined to designate as smoke every gas which they can see. It may suffice for present purposes, however, to consider "smoke problems" as covering the gaseous products from burning carbonaceous material, carrying uncombined carbon particles in suspension in such quantities as to appear black, brown or gray, while "fume problems" cover gases carrying in suspension extremely finely divided particles which have resulted from quick condensation of vapors or gases, as, for example, arsenic trioxide.

"Dust problems" refer to fairly large solid particles suspended in gaseous bodies. The dividing line between "fume" and "dust" is not sharp, and oftentimes collected dust may be a mixture of "fume" particles and "dust" particles.

When the suspended particles are liquid, the term "mist" is generally used. Example: sulphuric acid mist, which contains minute drops of sulphuric acid of any strength. A "mist" is readily produced when saturated steam is suddenly mixed with cool, humid air. This "mist" is the so-called "visible steam." It may contain other water in the gaseous condition. Clouds and fogs are excellent examples of how readily these finely divided particles may be kept suspended in a gaseous body, and at the same time they indicate how futile it is to expect settling chambers to cause the deposition of all of the small particles carried through them by moving gases. Fogs are produced by two portions of the atmosphere, generally of different temperatures and humidities, commingling and producing a condition of supersaturation, the excess water being "fogged out."

The problems of removing from gases minute particles suspended therein are of great variety, and exist not only in thickly settled industrial communities but also in the sparsely settled States of the Middle West and Far West as well as the South. Requests for a solution of specific problems have been received from northeastern Canada, Cuba, Mexico, Hawaiian Islands, and far-away Alaska, to say nothing of inquiries from across the seas.

In New York City inquiries have ranged from the collection of diamond chips suspended in a small volume of air up to the collection of cinders and small pieces of coke from gases arising from boilers under which about 3000 tons of coal are burned every twenty-four hours. This volume of gas would fill the entire cubical space occupied by the Equitable Building in about three minutes. It is obvious that the saving of values was the object to be attained by collecting the diamond chips, while in the latter case the cinders and coke particles constituted a serious nuisance in the neighborhood.

Black smoke is so common that its origin needs no further reference than to say that practically every furnace fired with bituminous coal may occasionally offend, while some offend almost continuously due to the method of firing. Railroad locomotive engine-houses (roundhouses) are generally causes for complaint from residents of the neighborhood, as there are usually several fires being built or maintained in such manner as to produce large quantities of dense black smoke. Locomotives in rapid motion are not such direct offenders, but the accumulation in the atmosphere of smoke from several hundred such fires soon produces its effect throughout the district served.

Plants in which dry, finely divided materials are handled or grinding operations conducted generally have the problem of confining the dust either for saving values, or for sanitary reasons or for preventing nuisances. Sometimes dusts floating around a plant are very detrimental to rapidly moving machinery. Portland cement plants generally have severe dust problems as they feed finely ground materials into long cylindrical kilns near the point where large volumes of gas are rapidly emerging, and in such a manner that the gases pick up a large quantity of dust. Instances are known where the quantity of dust from a cement plant approaches from 200 to 400 tons per day. This dust is scattered broadcast over the district surrounding the plant.

At iron blast furnaces the finely divided ore is charged in such a way that dusting is facilitated. Reports have been obtained which show that the total amount of iron ore and coke lost in this manner amounts to a very large tonnage yearly, and when it is considered that this dust may be worth from $3 to $3.50 per ton the economic loss is better appreciated. The presence of this dust in the blast furnace gas is highly objectionable from other standpoints when the gas is to be used in gas engines for direct conversion into mechanical power, or burned in hot blast stoves or under boilers for conservation of the heat energy. Further, careful calculation has shown that by removing the particles from the gases from one iron blast furnace, without cooling the gases, the value of the conserved heat energy might amount to about $25,000 per annum. One corporation is said to control at least 100 furnaces. Therefore the saving in this way alone would approach $2,500,000 an-

*An address made before the First National Exposition of Chemical Industries in New York City.

nually. Now add to this the value of the ore recovered in a usable form, the value of the water used in wet-cleaning methods and the power for pumping it, the value due to better hot-blast stove operations, saving in stove and boiler brickwork, labor, etc., and the economic value of electrical precipitation in this one field of industry can easily be appreciated.

In the large smelteries of the Rocky Mountain States the fume and dust problems are of great importance, not alone because of the strife between the farmers and the smelting companies on account of crop damage but because of the huge economic waste occurring in the operations. It is true that other serious problems are to be met in addition to the collection of the suspended solids before the millenium is reached. Markets must be created or extended; transportation must be arranged; new metallurgical and chemical processes must be developed for separating the components of materials now considered valueless. It is true that rapid progress has been made, but much more remains to be accomplished.

While sulphur is being mined in Louisiana and prepared for the market as a distinct enterprise, and some sulphur and certain sulphur compounds are imported from foreign countries, yet the amount of sulphur being wasted in the smelting of valuable ores is extremely great. It is not unusual for a fair-sized smelter to waste 1000 tons of sulphur daily by discharging it into the atmosphere in the form of a gas sulphur dioxide. And this is being done notwithstanding the fact that sulphur is a very necessary commodity for members of a civilized nation. It is the most difficult to obtain of any of the constituents of sulphuric acid, the basis of chemical industry. Some smelting companies are manufacturing sulphuric acid from their previously waste gases. But there is a limit to the market for the grade of acid they produce.

It is evident that other remedies must be sought. Some serious efforts are being made to reduce the sulphur dioxide to elementary sulphur, as in this form it can be stored, shipped or used more universally than if converted directly into sulphuric acid, which is about three or four times as heavy as the sulphur contained, depending upon the acid's concentration. Where smelting operations are so situated as to prevent shipping acid to available markets, some sulphuric acid is being used to extract values from low grade ores which heretofore did not warrant treatment by older methods. Further progress will undoubtedly be made in the future.

Waste gases at smelteries and refineries also contain metals such as copper, lead, zinc, tin, gold, silver, nickel, and even less commonly known elements such as arsenic, bismuth, selenium, tellurium, palladium, antimony and various chemical compounds containing these. The recovery of these materials often would be warranted for the additional revenue which they would produce even under present circumstances; in others, it is desirable to develop processes for separating the constituents of the collected fume and dust. Investigations at one smeltery showed that metals having a gross value of approximately $4,000 per day were being discharged into the atmosphere. The expense of collecting, smelting, refining and marketing the valuable ingredients becomes an important item, and thus it behooves metallurgists, chemists and engineers to devise cheaper methods of handling such problems.

The arsenic which can be produced from the waste gases of one Western smeltery would much more than equal the entire United States consumption. In order to allow for placing all of this arsenic on the market further uses must be found for it, otherwise it must continue to settle upon the ground in the surrounding district or be collected and stored until a use is developed for it.

While discussing markets it may be well to state that price alone does not control the consumption of all product. At various copper refineries on the Atlantic Seaboard some selenium is produced, for example. In the elementary form this may sell for around $1 per pound, and yet, strange as it may seem, large quantities of it are being thrown into sewers. Contrary to the generally accepted theory, dropping the price to even 10 cents per pound would not find a market which would consume all that is now being wasted. This is because of the peculiar properties attached to this element. It can be used for but few things, and even for these in limited amounts only. When chemical research has discovered additional uses for selenium, and likewise for tellurium, this apparently paradoxical situation may be relieved.

The daily press has contained much in recent months concerning brass and the necessity for high-grade zinc. Extensive investigations in large brass foundries have shown that perhaps 3 per cent of all of the zinc charged into the crucibles is burned off or volatilized and then passes up stacks and is discharged into the atmosphere, thus constituting an economic loss aggregating many thousands of dollars per annum. Analyses of material collected from the stack gases showed a zinc content of about 55 to 60 per cent, mostly as zinc oxide. Small amounts of cadmium and other compounds are present, but it seems possible to convert all of this zinc heretofore wasted into high-grade zinc, and this would be a distinct and important gain from an economic standpoint as well as being a source of profit to the owners of the foundries.

In the production of metallic zinc from ore a considerable percentage of zinc is lost as fume. In the industry this is known as "ventilator loss," as all of this white fume passes through large stack-like openings in the building roof just over the bank of retorts. This loss amounts to many thousand dollars per annum.

In refining copper electrolytically, gold, silver and other materials are collected as slimes. When these latter are treated in a furnace for the recovery of the gold and silver considerable of these materials are lost as fume. In one plant near New York City these valuable fumes are being collected by electrical precipitation, and whereas previously the actual losses were several thousand dollars per annum, this has been so reduced that probably it does not now exceed $300 per annum.

There has been produced at this plant a situation which is interesting in showing how progress comes in stages. Prior to 1912 apparently little if any attention was given to the fumes, since their value was considered to be beyond recall and to be not great in any event. After their recovery had been proven it was considered a very serious matter to allow fumes to escape for more than a few minutes while repairs were being effected, those in charge saying that "it cost $1 for every minute the fumes were allowed to escape."

At a sulphuric acid plant where a large quantity of acid is concentrated in stills considerable mist is made which is considered a nuisance. Investigation showed that 2 to 3 tons of sulphuric acid were being wasted daily as mist. Here is an excellent example of a combined nuisance and value problem.

At another plant hydrochloric acid fumes had been killing vegetation in an adjacent park, but at present the trees and shrubs are thriving, as the acid fumes are being collected electrically. Fume and dust problems may exist within certain manufacturing operations, such as, for example, in the production of sulphuric acid

by the contact process. Sulphur either free or combined with other elements is burned in roasters, the object being to produce sulphur dioxide. These gases (primarily air plus 6 to 7 per cent sulphur dioxide) generally contain dust and fume and some sulphur trioxide, either free or combined with water, to form sulphuric acid. In order to further oxidize the sulphur dioxide to trioxide the gases are passed over a catalytic substance (ordinarily some form of platinum), and in order that the catalyzer be effective the dust should be removed from the gases and the cleaned gases brought to the catalyzer at a temperature of about 400 deg. C. Furthermore, all arsenic, selenium, antimony, lead, etc., and their compounds must be removed as must nearly all sulphuric acid and water vapor. After the conversion to trioxide has been accomplished the absorption of the product by concentrated acid is quite readily accomplished.

It will be seen, therefore, that the removal of dust and fume must be carried out completely and all other harmful impurities eliminated from the gases. Furthermore, the heat resulting from the combustion of the sulphur in the roaster should not be sacrificed. In this industry, therefore, there are some very important dust and fume problems, the importance of which is not based on values in the dusts nor upon neighborhood nuisances, but rather on the improvement of manufacturing operations. Similar problems exist in other industries.

In ventilating modern public buildings, and even up-to-date factory buildings, it is considered desirable to control the temperature and humidity of the air and remove all dust, bacteria, etc. In one recent installation it has been found that by circulating 50,000 cu. ft. of air per minute in a closed system, removing dust, etc., by electrical precipitation, the saving in steam which would be required for preheating this quantity of air in cold weather much more than pays a good return on the investment. Here it is noted that the primary object was conservation of steam for preheating ventilating air.

One of the most interesting problems in dust removal which has been brought up for consideration in conjunction with an ingenious suggestion pointing to its solution has been in connection with the cleaning and ventilation of the present subways. During the small hours of the night, specially equipped cars were to be operated from one end of the subway to the other, these cars to be provided with air-jets or blowers in front so as to stir up all of the dust on the floor, walls and ceilings. The rear of the car was to be equipped with apparatus for sucking in the air and contained dust. This air was to be subjected to electrical precipitation to remove the dust therefrom and thence discharged through the air-jets at the front. This whole arrangement might well be called a giant, portable vacuum cleaner. Perhaps the problem warrants some such equipment, but it would seem that the tracks should be separated by partitions if the scheme is to work satisfactorily.

Reference is hereby made to the article in the Annual Report of the Secretary of the Smithsonian Institution for 1913 by Dr. Frederick G. Cottrell, entitled "Problems in Smoke, Fume and Dust Abatement," and to an article by the author, entitled "Practical Application of Electrical Precipitation," appearing in the April, 1915, *Proceedings* of the A. I. E. E. These two papers give a more extended account of electrical precipitation and are accompanied by bibliographies, thus enabling anyone interested to obtain further details than are given in this paper.

The statement has already been made that the progress with this particular industry has far exceeded that in any other country. While a member of the faculty of the University of California, Dr. Cottrell conducted experiments in electrical precipitation, and as these were so successful the work was transferred to near-by smelteries and acid plants. To him must be given full credit for the ingenious and practical method which is used for getting the proper kind of electric field, and for developing rational hypotheses and working bases for solving all kinds of fume, dust and smoke problems by electricity. Dr. Cottrell and his associates, Messrs. Heller, Miller and O'Neill, also of California, generously donated their United States patent rights to the Research Corporation of New York City to be used as an endowment for scientific research. This corporation is controlled by a board of directors, each member of which is giving his time and energy gratis for the benefit of this public movement. This unique organization is described and its objects are fully set forth in a paper, entitled "The Research Corporation; an Experiment in the Public Administration of Patent Rights," which appeared in the records of the Eighth International Congress of Applied Chemistry.

The desire of Mr. R. B. Mellon of Pittsburgh to have the coal smoke nuisance in that vicinity eliminated was one of the motives leading to the establishment of the R. B. Mellon Smoke Fellowship of the University of Pittsburgh under the direction of the late Dr. Robert Kennedy Duncan. Partly as a result of the efforts of those engaged in this investigation, the Messrs. R. B. and Andrew Mellon have established the Mellon Institute of Industrial Research and School of Specific Industries, which has such an excellent mission to fulfill in advancing chemical progress. Mr. Mellon likewise has generously donated to the Research Corporation the results obtained by the Smoke Fellowship.

Consideration of the problems heretofore mentioned should suffice to show that some very interesting and valuable problems exist in which extremely finely divided particles must be separated and removed from gases of various kinds, temperatures and volumes.

It was pointed out that settling chambers do not and cannot adequately answer the purpose, since it is necessary to cause some force to act upon the particles in a readily controlled manner and in such a way that they will move away from the moving gas which serves to keep them suspended and separated. With a proper arrangement of pipes or plates and wires acting respectively as "collecting electrodes" and "discharge electrodes," it is possible to produce a discharge of electricity from the wires to the pipes or plates through gases present between them. For convenience the statement is made that this discharge consists of a number of units of electricity, the term being applied as one would use, say, pints of water.

When this discharge is taking place with sufficient rapidity (i.e., enough units of electricity are flowing through the gas in a unit of time), a beautiful violet light can be seen around the wires. It is true that ordinarily air and other gases are considered as unable to conduct electricity, but in electrical precipitation it is customary to employ very high voltages, such as, say, 75,000 to 100,000. With such voltages as these it is possible to subject a gas to such strains that it is changed from a non-conducting to a conducting medium. Of course, the conductivity is not of the first order of magnitude such as possessed by copper, nickel, etc. The discharge and collecting electrodes are not mechanically connected in any way, but on the contrary are necessarily kept spaced apart and insulated one from the other by high-voltage insulators. A large number of discharge electrodes may be connected by metallic wires or plates, and this is likewise true of the collecting electrodes, it being necessary only to keep these two kinds

of electrodes in proper relation with each other so that the units of electricity are compelled to flow through the air or other gases present between them.

To further explain the phenomenon of electrical precipitation, the suspended particles may be compared to a pith ball in an experiment on static electricity. Each of the particles of dust or fume collects a charge of one or more units of electricity of the same polarity as the discharge electrode. Now since two bodies charged with the same kind of electricity repel each other it would naturally be expected that the particles would be driven away from the wire and drawn toward the pipe or plate (collecting electrode). Enough units of electricity must be discharged from the wire or "discharge electrode" or otherwise produced to charge the particles suspended in the gas as it passes between the electrodes. The more units of electricity upon a particle the greater is the force acting upon it, therefore in practice a strong discharge is maintained. Furthermore, the greater the voltage between the electrodes the stronger is the precipitation force. This makes it desirable to operate at a voltage just below that where a spark or arc would form. Moving gases exert a force upon suspended particles, and the greater the velocity the greater is this force. Hence with a given precipitating apparatus there is an upper limit to the gas velocity at which the suspended particles may be completely removed.

If the polarity of the electrodes is too rapidly reversed, the particles will remain in suspension in the gases. For this reason direct current at high voltages is required, as alternating current at commercial frequencies is not suitable for this work. Large volumes of gases require, as a rule, more power than smaller volumes, but the power consumption is affected by other factors. Static machines do not furnish enough power for commercial installations and are not dependable. However, they give a desirable kind of current and potential for the work. In commercial installations the gases may pass between the electrodes in either a vertical or a horizontal direction. Ordinary black iron pipes about 12 in. or 18 in. in diameter by 15 ft. to 20 ft. long are in general use. These pipes may be connected to a gas chamber at each end in a manner similar to that in a tubular boiler. With this arrangement gases and suspended particles may readily be distributed to the various pipes and through them to another gas chamber having been cleaned during such passages. The cleaned gases may be conducted to other places as desired.

The precipitating apparatus may be designed for either hot or cold gases, and for corrosive or non-corrosive materials, and the product may be collected either wet or dry as conditions may indicate. In treating gases containing particles of acid held in suspension, materials such as lead or stoneware are employed to avoid serious corrosion. Heat-insulating materials may be employed in the apparatus to lessen the loss of heat energy when desired. The gases may be either forced or pulled through by fans or other mechanical means, or if the gases are sufficiently warm natural draft may be employed. When treating gases which are explosive when mixed with air, they are kept under a pressure at least slightly greater than atmosphere until they have been cleaned.

The high-voltage direct current is obtained by transforming low-voltage alternating current into high-voltage alternating current and then converting or rectifying the latter into an intermittent, high-voltage direct current. The amount of power required in commercial installations is relatively low, generally being much smaller than that necessary for any other gas-cleaning system.

A unique advantage of electrical precipitation is its ability to collect even the most minute particles. Another interesting feature is that components of gases of different volatilities may be separated by what has been termed "fractional precipitation." In this method the gases are treated while at a high temperature to remove those materials which are then either solid or liquid, and then after further cooling the gases subjecting them to another treatment in a separate precipitator. Arsenic trioxide of high purity has thus been separated from copper, iron, zinc and other materials. It would be possible to obtain water-free tar in gas plants by this means, and also it might be possible to collect tars of different compositions. This offers a fertile field for investigation at gas plants.

At foundries where old tin cans and other waste metals are melted and poured into sash weights, quite large tonnages of fumes high in tin, lead and zinc are being wasted into the atmosphere. While the gross value of this material may be, say, $100 daily, the fact that these elements are present in such proportions as to render their separation difficult and very expensive by present methods permits owners of these plants to continue such wastage. Research should disclose some practical and economical way of separating these constituents.

In smelting ores of certain districts for the production of copper, the contained lead is generally eliminated from the copper matte in the converters. This fume has heretofore been wasted, hence the lead in such ores was of no value in so far as it never reached a market. Now that this valuable fume can be recovered and the lead marketed, it should be good practice to charge more such ores into the furnaces instead of studiously avoiding them.

There is a large tonnage of galvanized sheet-iron scrap produced yearly, the zinc on which is generally wasted. In some plants this material is charged into open-hearth steel furnaces and the zinc driven off into the atmosphere as fume. By concentrating this material at certain locations, the recoverable zinc fumes should warrant its collection. A somewhat similar problem exists at some iron blast furnaces, the ore containing zinc in such quantities as to warrant its recovery from the blast furnace gases. An interesting situation has been found at other blast furnaces which indicates a nice research problem. It was noticed that there were white fumes in the gases from the boilers, these being heated by blast furnace gas, burned after being wet scrubbed. A study of these fume-laden gases showed a quite large tonnage of potash compounds which, if collected and properly treated, would make excellent fertilizer.

Many other instances could be given, but it is believed that these will be ample to convince that air and other gases contain values far beyond and of a greater variety than that which is generally understood. It is hoped that chemists, engineers and others will give more earnest consideration to smoke, fume and dust problems and endeavor to solve them, not only for the sake of better atmospheric conditions and for aesthetic reasons, but also for the values which are to be obtained when their solution is accomplished.

Research Corporation,
New York City.

The Buffalo Foundry & Machine Co., Buffalo, N. Y., has opened an office in New York City in the Whitehall Building, 17 Battery Place.

Metallurgical Clay Goods—The Denver Fire-Clay Co., Denver, Col., has issued Bulletin 100, describing its muffles, crucibles and scorifiers and giving instructions for their care and use.

The Electric Arc in Vapors and Gases at Reduced Pressures*

BY W. A. DARRAH

Present commercial arc lamps operate with few exceptions in an atmosphere rich in oxygen or the oxide compounds of the electrodes. As a result the electrodes are oxidized as rapidly as they are vaporized (if not already composed of oxides as in the case of a magnetite arc), and as the oxides cannot be used again commercially it is necessary to provide means for disposing of them. This cycle of vaporization and oxidation of the electrodes naturally results in their comparative rapid consumption, which necessitates the trimming and cleaning of the arc lamp—one of the large factors of arc-lamp operation.

If it were possible to so design the lamp that the supply of material for the arc did not come from the electrodes but from a surrounding gas or vapor, and if in passing through the arc the vapor were not destroyed, it would then seem to be possible to construct an arc lamp which would not require trimming or materially more attention than an incandescent lamp. A lamp of this type, if it had a white light and good efficiency, might in some cases even occupy the field of the present incandescent lamp.

The research which is described in this paper was carried on to investigate the possibilities of accomplishing this object, and while the results are very promising from a practical standpoint, they are outlined here for their scientific value and should be considered only as a scientific research.

A study of the light efficiency of an arc from a chemical standpoint shows that there is a certain rather limited class of substances which when introduced into the arc in small quantities produce a very great increase in luminosity. Thus the addition of small quantities of cerium or calcium compounds to the carbon arc may increase its efficiency over 300 per cent, and the addition of titanium (preferably as an oxide) to the magnetite arc similarly produces an increased luminosity without a corresponding increase in energy consumption.

It is a peculiar coincidence that the addition of cerium or calcium to the magnetite arc, or titanium to the carbon arc does not result in approximately the same gain in efficiency. The chemical compounds in which the element appears is apparently of little importance.

A study of these facts led to the conception that perhaps an arc could be maintained in a closed vessel and supplied with these light-producing elements in the vapor form. On investigation this did not seem impractical, especially after a consideration of the liquid "inorganic" compounds shown in Table I, which contains some of the elements which produce highly luminous arcs. The table is discussed at length later on in this

TABLE 1—EFFECT OF VAPORS ON ARC

Substance	Boiling Point C°	Melting Point	Effect on Arc	Luminosity	Color
1. Carbon tetra chloride	77°	Liquid at ordinary temperature	Stable	Low	White
2. Stannic chloride	114°	Do.	Stable	Medium	Yellow white
3. Titanium tetra chloride	136°	Do.	Unstable Oscillatory Arc	Very high	White
4. Antimony trichloride	220°	Do.	Stable	High	Yellow white
5. Arsenic chloride	130°	Do.	Stable	Low	Purple
6. Silicon tetra chloride	57°	Do.	Unstable	High	White
7. Boron chloride	18°	Do.	Unstable	High	White
8. Phosphor trichloride	75°	Do.	Stable	Low	Pink and green
9. Aluminum trichloride	183°	Volatile	Do.	Low	Yellow
10. Cerium chloride	1400°	.....	Do.	Very high	White
11. Calcium chloride	1200°	780°	Do.	High	Strong yellow
12. Calcium iodide	1100°	740°	Do.	High	Yellow
13. Chromic chloride	White heat	.....	Unstable	Low	Green
14. Titanium chloro bromide	180°	.....	Very stable	Very high	White
15. Bromine	63°	7°	Very stable	Low (high absorption)	Yellow
16. Iodine	114°	Volatile	Unstable	Low	Blue
17. Chlorine	33°	102°	Stable	High	Yellow

*A paper read before the New York section of the American Electrochemical Society, in joint session with the Illuminating Engineering Society on November 11, 1915. Somewhat abstracted.

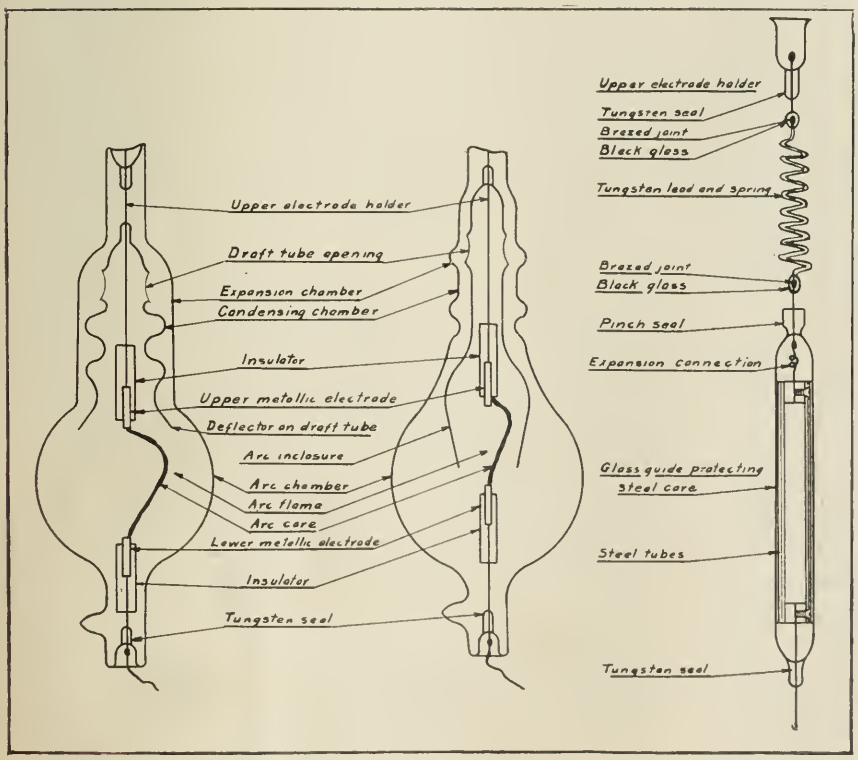
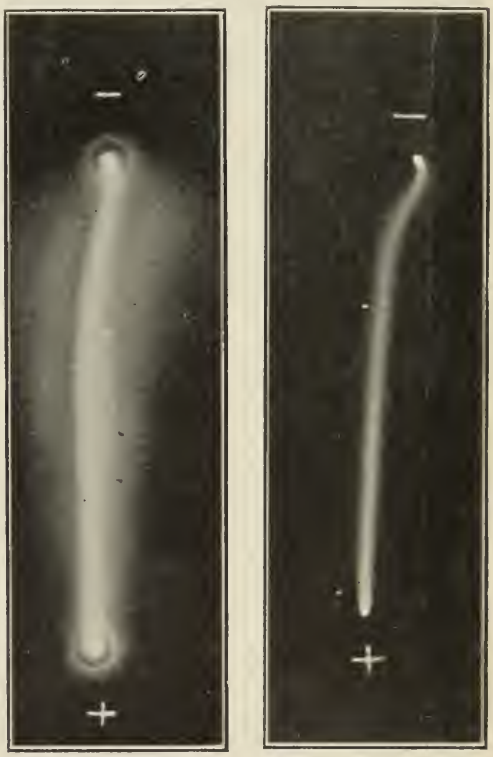


FIG. 1—LATEST CONSTRUCTION OF NEW ARC LAMP TYPE



FIGS. 2 AND 3—VIEWS OF NEW TYPE OF ARC

paper, but it is interesting to note that titanium, tungsten and other elements which increase the luminous efficiency of an arc, may readily be secured in the form of volatile liquids.

Accordingly, a crude apparatus was arranged in which two hard carbon electrodes were placed vertically above each other in a tight glass vessel, and an arc drawn between the electrodes. As might be expected, this arc was non-luminous and very unstable. Accordingly, a small amount of carbon tetra chloride was poured into the vessel with a rather marked result. The arc then became stable and could be drawn out to several times the length which was previously possible, although its luminosity was not much increased. A flaky soot formed by the decomposition of the carbon tetra chloride also filled the glass chamber. A trial was next made with stannic chloride, with a similar increase both in stability and allowable arc length. In this case, also, the luminosity of the arc was much greater. The stannic chloride, however, was decomposed by the air and moisture present, forming a white insoluble powder upon the walls of the chamber, soon shutting out most of the light.

A more elaborate apparatus was therefore constructed in which the graphite electrodes were separated by an electro-magnet acting upon an iron core within a glass chamber.

The air was exhausted from the chamber, a small quantity of stannic chloride vapor at a pressure of from 3 to 4 centimeters was allowed to enter and the arc drawn. Under these conditions a stable arc 3 to 4 in. long could be produced with 6 to 7 amp. direct current, and 220 volts impressed. The arc was intensely white and so steady that it had the appearance of a thick incandescent filament slightly bowed and surrounded by a flame-like less luminous shell of yellow. The vapors from this arc, however, soon collected on the walls, forming a dense brown coat, which proved to be mainly tin carbide with a mixture of stannous chloride and other intermediate compounds.

These preliminary tests having indicated possibilities as well as having shown the difficulties to be overcome, additional smaller lamps were constructed along somewhat improved lines.

With these a detailed study was made of the effects of the various available electrode materials as well as the different vapors and lamp designs.

For convenience a hard glass (manufacturer's number G-702-P) was employed, as this permitted the sealing of tungsten wires and rods directly into the globe by the use of a flux of potassium nitrite and borax. This allowed the free use of heavy seals which were necessary for the tests. Fig. 1 shows the latest designs which have eliminated many of the difficulties encountered.

The shapes shown in Figs. 2 and 3 were found fairly satisfactory, while Fig. 5 shows some later designs which eliminated many of the difficulties eventually encountered.

The type of lamp shown consists essentially of an arc chamber at the center of which the arc is drawn between two tungsten electrodes about 3/16 in. in diameter. The electrodes are partly surrounded with a refractory insulator, designed to prevent the arc from moving far from the ends of the electrodes, as this allows the magnetic blow of the arc to continue to extend it, ultimately tending to rupture the arc. The refractory insulator also assists in maintaining the electrodes at a high temperature, thus increasing the efficiency of the lamp and the stability of the arc.

The upper electrode is fastened by means of a tungsten rod to an iron core, which is surrounded by a glass shell to protect the iron from corrosion, as the vapors used readily attack nearly all metal except tungsten, platinum, gold and a few other inert materials. A flexible tungsten spiral serves to conduct the current from the upper movable electrode to the upper seal.

It was found after a number of trials that a certain combination of gases to be described later gave a minimum amount of "soot" (decomposition products), which gradually collected upon the globe, thus reducing the amount of light radiated. In order to overcome this difficulty the arc chamber was extended somewhat above the upper electrode, thus forming a condensing chamber in which the soot could collect, allowing the walls to remain clean.

Further study developed that while this would remove a large quantity of the suspended soot a certain amount was still deposited on the glass walls adjacent to the arc. In order to eliminate this deposit, a draft tube was placed around the upper electrode in such a position that the heated gases from the arc would pass upward through the draft tube out into the condensing chamber and then back downward into the arc chamber for use again. The corrugations shown on the draft tube and condensing chamber has the effect of slightly compressing and expanding the gas as it passes from a chamber of small volume to one of large volume. The alternate expansion and compression of the gases, as well as the contact with the walls thus produced, was found to materially aid the condensation of the suspended matter.

The search for a satisfactory electrode material developed that carbon, either in the form of graphite or in the amorphous state, was unsatisfactory because of the disintegration by the action of the vapors and also the deposit of free carbon which it caused on the walls of the arc chamber apparently by direct radiation, as the draft tube and condensing chamber did not affect it as much as an increase of pressure of the gas around the arc.

It was demonstrated that practically all of the materials available (see Table I) formed carbides under the influence of the arc, and these carbides mixed with free

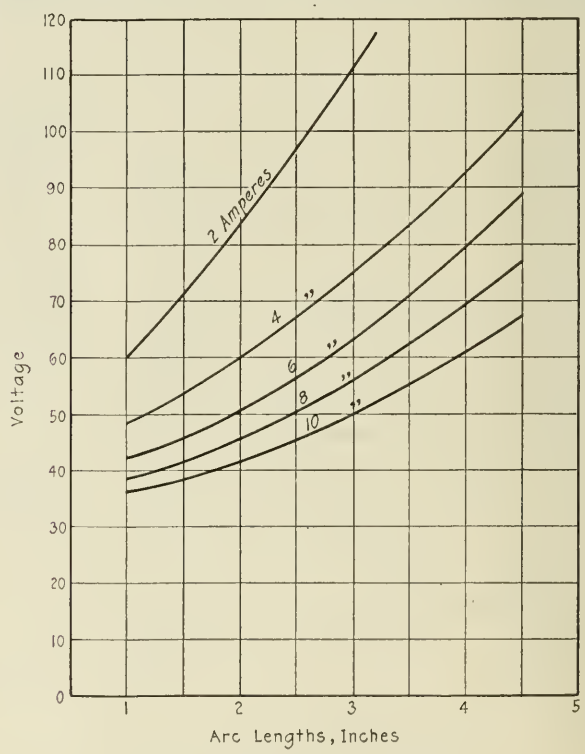


FIG. 4—PERFORMANCE CURVES

carbon formed so heavy a deposit on the walls of the arc chamber that it was decided to abandon carbon.

Chromium, titanium, molybdenum, nickel, iron, and silver were all tried without satisfactory results. Decomposition of the electrodes, decomposition of the surrounding gases and heavy deposits on the globe made the use of these materials impractical.

The substance which was found to be satisfactory in all respects was tungsten, which proved to be practically inert even at a white heat in the presence of the various vapors used. The tungsten terminals, moreover, did not melt or evaporate in the arc except at a very slow rate, which seemed to be comparable to the evaporation of the filament in an incandescent lamp. A rather interesting phenomena resulting from the gradual evaporation and deposition of the tungsten electrode was exhibited in the growth of a thin star-shaped fringe on the edges of the arc surfaces of the electrodes. This fringe was composed of points 2 or 3 millimeters long formed of small needle-like crystals of tungsten, and appears to be caused by the slow precipitation of free tungsten from the surrounding gases under the influence of temperature changes.

Having devised a satisfactory construction it was found that in order to introduce the gases and eliminate air and moisture special methods were required.

As all of the liquids employed are hygroscopic, and many of them readily decomposed by ordinary moist air, it became necessary to exhaust the air from the lamp, heat the lamp and electrodes while at a low pressure in order to remove the air films and then admit the liquids without opening the lamp chamber to the air. This was accomplished by means of a bottle sealed to the lower extremity of the lamp and provided with a ground stop cock connecting it with the lamp, as shown in the photographs. After the proper degree of exhaustion was reached, the desired liquid was carefully poured into the bottles and the stop cock opened slightly when atmospheric pressure forced the liquid into the lamp chamber.

The appearance of the arc in this lamp is quite different from other commercial arc lamps (see Figs. 2 and 3).

It is usually very stable, about ⅛ in. in diameter, tubular in form and varies from 2 to 5 in. in length with 110 volts direct current applied, the variations being due to differences in pressure, natures of the gases supplied, etc. A high pressure naturally increases the intrinsic brilliancy of the arc, but makes it necessary to operate at a shorter length as the gas currents due to temperature differences and arc reaction are correspondingly more violent. The diameter of the central luminous tube is also reduced with an increase in pressure.

Some of the arcs revolve very slowly, but as a rule the low pressure of the gases minimizes the motion of the arc and the general appearance is that of a thick intensely white incandescent filament slightly bent at the upper end. With some of the vapors, as, for example, the metaloid halogen compounds, antimony, phosphorus and arsenic chlorides, the central tubular portion is surrounded by a ragged flame, which is light pink in the case of arsenic and pale green in the case of phosphorus.

The flame portion acts somewhat as an absorbing screen, thus reducing the total useful radiation. It is a curious fact that this flame may exist for a short but appreciable time after the circuit has been interrupted, thus indicating that it probably does not have a part in the conduction of electricity through the vapor, but appears to be a zone in which the vapors after being dissociated by the heat and electrical effects of the arc recombine. The spectrum of the flame is usually quite different from the arc spectrum, and is characteristic of the elements involved, while the spectrum of the arc independent of the ends of the electrodes (which, of course, give a hot body spectrum) is usually a band spectrum and is practically continuous except for a few absorption lines.

A curious phenomenon noticed with an 8-amp., 220-volt arc at low pressure in the presence of cerium chloride was a separated arc which gathered into a glowing sphere at one corner of the chamber while the space between the electrodes through which a current of 8 amp. passed was entirely dark.

The complete paper contains typical performance curves which indicate the electrical characteristics of the antimony pentachloride lamp, which is illustrative but does not have as high an efficiency as the titanium tetra chloride or titanium bromo chloride lamp.

Fig. 4, plotted between arc length and voltage, shows the rate at which additional arc lengths require an increased voltage. The curve is also interesting as indicating that a 4-in. arc at 10 amp. requires no more voltage than a 1-in. arc at 2 amp. In other words, a 10-amp. arc is four times as long and therefore emits four times as much light as a 2-amp. arc. In addition its intrinsic brilliancy is about five times that of a 2-amp. arc. Accordingly, the light emitted by a 10-amp. arc *under these conditions* is twenty times that of a 2-amp. arc, and since the wattage of a 10-amp. arc is only about five times that of the 2-amp. arc, the efficiency is approximately four times that of the 2-amp. arc.

Efficiency curves indicate that 20 amp. is approximately the point of maximum efficiency of this particular antimony pentachloride lamp. It should be understood, however, that the current of maximum efficiency differs widely with differences in the nature and pressure of the gas as well as the volume and available radiating surface of the lamp, and very efficient titanium bromo chloride lamps have been constructed with a maximum efficiency of about 5 amp.

Regarding the efficiency secured, it is to be expected that these will vary widely with the condition and nature of the vapors used, and actual results range from 1 watt per mean spherical candle-power to less than one-quarter of the value. This performance may be secured with a white light which closely resembles afternoon daylight (north sky). An analysis of the color of the arc with the spectroscope as well as color-matching tests confirm this fact.

As a matter of interest, Table I shows some of the different compounds tested and some of the general results secured. These compounds may be roughly divided into three classes, as follows:

1. The illuminants, or those materials which give a high luminous efficiency. They usually produce unstable arcs if used alone.

2. The stabilizers, or those compounds which have a low luminous efficiency, but when introduced into an arc allow a very stable arc at relatively low voltages.

3. The "catalizers," or those compounds which are introduced to assist recombination in the flame zone, thus minimizing deposit.

Table I is interesting as it is the peculiar properties of the compounds, many of which are not very commonly used, that render possible a lamp of the kind described. The problem is to introduce as dense as possible an atmosphere of the various illuminants as titanium tetra chloride into an arc in such a form that it will not be permanently decomposed but may be used again and again. Some of the liquid halogen compounds shown in the table allow this. Some of those compounds (as, for example, those with the metaloids) which have a relatively slight affinity for a halogen are too readily

decomposed to be useful. Others, like stannic chloride, are too readily reduced to a less oxidized state, passing from a tetra chloride to the dichloride. Titanium tetra chloride is an example of this condition, but the addition of a small quantity of free bromide to the $TiCl_4$ (in which it is readily soluble) forms a compound (the bromo chloride) which readily recombines after dissociation.

Fortunately also, since the chloride and bromo-chloride of titanium dissociate at a higher temperature than tungsten chloride, and therefore recombine at a higher temperature than tungsten chloride, these vapors will not attack metallic tungsten even in the presence of the electric arc.

In order to avoid oxidation effects it was necessary to eliminate all oxides from Table I. More complex compounds such as sulphates, nitrates, could not be considered because of the tendency to dissociate and not recombine. Sulphides, nitrides, phosphides, etc., were eliminated because the chemical stability of these compounds in most cases was too slight to be satisfactory.

Chlorine was the halogen most generally used because of the stronger union of the chloride, and the reduced tendency of the dissociation products to attack the tungsten electrodes.

It would appear that an investigation along the lines here described opens up new possibilities in light production, but it cannot be too strongly emphasized that while the results set forth in this paper offer considerable promise from an applied, practical standpoint, yet they are not presented for consideration as representing a finished device, but merely a research in what seems to be a new and interesting field.

Mr. **Paul O. Abbe**, New York City, has issued a profusely illustrated catalog (A) describing his crushers, jar mills, pebble mills, mixers, disintegrators and various other classes of machinery.

The American Blower Co. of Detroit, Mich., has issued a bulletin describing Sirocco service in large hotels and office buildings.

Pyrometer Recorder—The Wilson-Maeulen Co., New York, has issued a catalog describing the Tapalog, a multi-record, multi-color pyrometer recorder. A description of this recorder was given in our issue of April, 1915, page 260.

Fuel Oil Engines—Messrs. Samuel L. Moore & Sons Corporation, Elizabeth, N. J., has issued a catalog describing its "Crescent" fuel oil engines for isolated stations. This engine operates on low grades of fuel oil, alcohol, hydrocarbon oil or kerosene.

The Richardson-Phenix Co., of Milwaukee, Wis., has sent us Bulletin No. 50 describing the Phenix force feed lubricator and a new type known as model "T," and Bulletin No. 60 containing information on the new model "M" lubricator.

The Yarnall-Waring Co. of Philadelphia, Pa., reports great activity in recent sales of "Lea" V-notch Recording Liquid Meters. Among the chemical and metallurgical companies using them are the American Smelting & Refining Co., the Atlantic Refining Co. and the Aluminum Co. of America.

Investigations of a Source of Potash—The United States Geological Survey in a report just issued (Bulletin 620-J) has suggested that a possible source of potash may exist in the tailings piled up at the concentrating mills of the big copper mines in the West. The potash, however, is combined in the form of silicate minerals, and its extraction has not yet been accomplished commercially, although for several years it has been the subject of much study.

The Development of Refined Tars for Use in Road Construction and Maintenance *

BY PHILIP P. SHARPLES

The year 1915 marks a decade in the application of refined tar to road treatment in the United States on any extensive scale. Experimental work had been done in desultory way before 1905, but the big influx of automobiles in 1905 made the problem of the maintenance of automobile-traveled surfaces acute and stimulated search after a remedy. For road work tar was first practically used in Nice in 1901 by Dr. Guglielminetti.

The problem of finding the most suitable tars for any given use in road work is not an easy one. The variables besides the tar are so many that it is often difficult to assign the exact causes of any success or failure. The observer in comparing different experiments must know not only the chemical and physical characteristics of the refined tar, but must have knowledge in a technical way of the engineering specifications under which the work was undertaken and an actual knowledge of the weather conditions under which the work was prosecuted with an intimate acquaintance with the climatic and traffic conditions imposed upon the road after completion.

The refining of the tar was the first step forward, and since 1905 practically only refined tars have been used in the United States for road purposes.

At the beginning of the decade, the intelligent study and testing of coal tars and coal-tar pitches for industrial uses had only begun. The rule of thumb was still the rule of the tar distiller and the manufacturer's chemist had presented to him not only the development of a new material but the development of methods of testing, the valuation of raw materials, the methods of factory control and the standardization of the finished product. The success attained has reacted on the whole tar distilling industry in the United States and now every plant of any size is equipped with a good chemical laboratory and one manufacturer even sustains a research laboratory unattached to any plant for investigating the scientific problems constantly arising in the industry.

The tar distiller is at the start confronted by a great diversity in raw materials. The tars may roughly be divided into two great groups, the coal tars and the water-gas tars, which differ essentially in chemical and physical characteristics. The coal tars form the basis for by far the larger percentage of the refined tar used for road purposes. The water-gas tars usually require modification by admixture with coal tars or with other bitumens to make them available for road purposes.

Coal tars are further divided for purposes of classification and manufacture into several groups based on their origin. The tars differ markedly one from another in physical properties. Their characteristics are shown in Table I to which is appended a sample of water-gas tar for the sake of comparison. Although the samples are typical of the groups, other tars in the same groups would show much variation in individual test.

Table I—Comparative Analyses of Tars

Tar From	Specific Gravity at 15.5° C.	Specific Viscosity Engler 100° C.	% Free Carbon	% Oil to Soft Pitch	% Tar Acids on Oil
Horizontal retort gas works, high heat	1.293	30.0	37.5	....	....
Horizontal retort gas works, low heat	1.267	21.8	28.9	13.2	14.0
Inclined retort gas works	1.238	14.9	24.3	14.3	21.0
Semet-Solvay coke oven plant	1.187	3.0	10.8	21.8	4.0
Vertical retort gas works	1.153	2.1	4.0	28.8	29.0
Water gas plant	1.074	1.6	0.3	45.1	0

*Presented at the First National Exposition of Chemical Industries, New York City, September, 1915.

The difference in specific gravity, specific viscosity and free carbon is marked and they vary directly. The amount of oils produced when the tars are distilled to a soft pitch varies inversely. Samples of other tars might not fall so regularly into the groups but the main comparison holds true. The tar acids, on the other hand, are much more irregular, though coke-oven tars usually contain lower percentages than gas-works tars. Oil tars, though usually containing no tar acids, may at times show traces or contain a small percentage of tar acids.

The deduction is easily drawn that with such a variation in raw materials, a uniform refined product is only possible with the command of considerable variety of tars and strict laboratory control. A study of pitches of uniform melting point made from these same tars still further accentuates the importance of selection and control, as shown in Table II.

TABLE II—COMPARATIVE ANALYSES OF PITCHES

From	Specific Gravity at 15.5° C.	Melting Point Cube Method in Water, ° F.	% Free Carbon	% Fixed Carbon	% Ash
Horizontal retort gas works (1)	1.357	127	46.1	51.5	0.14
Horizontal retort gas works (2)	1.306	131	33.5	42.0	0.21
Inclined retort gas works	1.284	130	30 4	37.9	0.10
Semet-Solvay coke oven plant	1.281	133	19.3	28.8	0.48
Vertical retort gas works	1.225	145	10.4	19 1	0.23
Water gas plant	1.190	139	1.1	23.8	0.06

The specific gravity, the free carbon and the fixed carbon advance in the same order as the raw tars. The ash, however, seems to be independent of the origin and is of little moment in the valuation of the tars. A more detailed examination of the pitches would still further develop these differences and would emphasize even more emphatically the importance of strict laboratory control of both the raw material and the finished product.

Refined tars for road purposes are divided into the following groups according to the use to be made of them:

1. Binders used in the construction of macadam roads.
2. Refined tars for use in road-blanket treatments.
3. Refined tars used in cold-surface treatments.
4. Pitches used as filler in block pavements.

The practice in regard to the specifications covering these materials has gradually crystallized and the following may be taken as typical of the grades:

Road Binder

The specific gravity shall not be less than 1.22 or more than 1.28 at 60 deg. Fahr. (15.5 deg. C.).

The material shall have a melting point, determined by the ½-in.-cube method in water of not less than 100 deg. Fahr (37.5 deg. C.), nor more than 110 deg. Fahr. (43 deg. C.).

On distilling 100 grams of the material, no distillate shall come over below 338 deg. Fahr. (170 deg. C.). On continuing the distillation to 600 deg. Fahr. (315 deg. C.) not more than 15 per cent of distillate shall come over and the specific gravity of the entire distillate shall be not less than 1.03 at 60 deg. Fahr. (15.5 deg. C.). The residue from the foregoing distillation shall have a melting point not greater than 165 deg. Fahr. (74 deg. C.).

The free carbon shall be not less than 12 per cent nor more than 25 per cent.

In making the foregoing tests the following methods shall be used:

Specific Gravity

The specific gravity shall be determined by the use of a Hubbard type specific gravity bottle. Approximately 10 grams of the melted material shall be placed in the weighing bottle and the weight taken after cooling. Freshly boiled distilled water shall be added and the bottle kept in a bath at 60 deg. Fahr. (15.5 deg. C.) until no further contraction takes place. The water shall then be adjusted to the mark and the bottle removed from the bath and weighed. The weight of the material, divided by the weight of the water displayed is the specific gravity.

Distillation

A 250-c.c. Engler flask shall be used and 100 grams of the material taken for distillation. The apparatus shall be set up and the distillation conducted as provided for in the tentative method proposed by the American Society for Testing Materials, Proceedings Vol. XI, 1911, page 241.

The distillate shall be collected in weighed flasks and fractions shall be determined by weight.

Receivers shall be changed when the thermometer records a temperature of 338 deg. Fahr. (170 deg. C.) and when the thermometer records a temperature of 600 deg. Fahr. (315 deg. C.) the flame shall be removed.

Melting Point

A clean-shaped ½-in. cube of the material shall be formed in the mold, placed on a hook of No. 12 (B. & S. gage) copper wire, and suspended in a 600-c.c. beaker so that the bottom of the cube shall be 1 in. above the bottom of the beaker (a sheet of paper placed on the bottom of the beaker, and conveniently weighted, will prevent the pitch from sticking to the beaker when it drops off). The cube shall remain five minutes in 400 c.c. of freshly distilled water kept at a temperature of 40 deg. Fahr. (4.5 deg. C.) before heat is applied. Heat shall be applied in such manner that the temperature of the water shall be raised 9 deg. Fahr. (5 deg. C.) each minute. The temperature recorded by the thermometer at the instant the material touches the bottom of the beaker shall be the melting point.

In determining the melting point of the residue after distillation, the initial temperature of the water shall be 60 deg. Fahr. (15.5 deg. C.) instead of 40 deg. Fahr. (4.5 deg. C.).

Free Carbon

The free carbon shall be determined by making a hot extraction of 5 to 10 grams of material with C. P. Toluol followed by C. P. Benzol, or C. P. Benzol followed by chloroform as solvents. The extraction shall be made in a Soxhlet, Knorr, Underwriters, or some other suitable extraction apparatus. The distillation of the solvent shall be continued until the washings run through practically colorless.

Refined Tar for Use in Road-Blanket Treatment

The specific gravity shall be not less than 1.20 or more than 1.26 at 60 deg. Fahr. (15.5 deg. C.).

The viscosity, tested by the standard Engler viscosimeter, shall be not less than 125 sec. nor more than 200 sec. for 100 c.c. at 212 deg. Fahr. (100 deg. C.).

On distilling 100 grams of the material, no distillate shall come over below 338 deg. Fahr. (170 deg. C.). On continuing the distillation to 600 deg. Fahr. (315 deg. C.) not more than 25 per cent of distillate shall come over. The specific gravity of the entire distillate shall not be less than 1.03 at 60 deg. Fahr. (15.5 deg. C.). The residue from the foregoing distillation shall have a melting point not greater than 165 deg. Fahr. (74 deg. C.).

The free carbon shall be not less than 12 per cent nor more than 22 per cent.

In making the tests, the methods already described shall be used. In determining the viscosity, the following method shall be employed:

Viscosity

The viscosity shall be determined in a standard Engler viscosimeter at 212 deg. Fahr. (100 deg. C.). Sufficient of the material shall be placed in the viscosimeter to bring the surface of the liquid to a level with the tops of the three levelling points. The time required to discharge 100 c.c. shall be recorded as the viscosity.

Refined Tar for Use in Cold-Surface Treatment

The specific gravity shall not be less than 1.14 nor more than 1.18 at 60 deg. Fahr. (15.5 deg. C.).

The viscosity tested by the standard Engler viscosimeter shall not be more than 250 sec. or less than 100 sec. for 100 c.c. at 104 deg. Fahr. (40 deg. C.).

On distilling 100 grams of the material to 338 deg. Fahr. (170 deg. C.) not more than 7 per cent shall distill over. On continuing the distillation to 600 deg. Fahr. (315 deg. C.) the residue shall be not less than 65 grams. This residue shall be a soft pitch at 60 deg. Fahr. (15.5 deg. C.). If the residue appears hard it shall be tested for melting point and the melting point shall not exceed 140 deg. Fahr. (60 deg. C.) by the ½-in.-cube method in water. The specific gravity of the entire distillate shall be not less than 1.01 at 60 deg. Fahr. (15.5 deg. C.).

The free carbon shall be not less than 4 per cent nor more than 12 per cent.

Pitch for Use in Stone Block with Fine Sand to Form a Mastic as Adopted by New York City

The coal-tar paving pitch shall be a straight-run residue obtained from the distillation of coal tar and shall comply with the following requirements:

(a) Melting point shall not be lower than 110 deg. Fahr. nor higher than 125 deg. Fahr.

(b) Free carbon shall not be less than 20 per cent nor more than 35 per cent.

(c) Specific gravity at 77 deg. Fahr. shall not be less than 1.22 nor more than 1.30.

(d) Specific gravity of the distillate to 670 deg. Fahr. shall not be less than 1.06 at 140 deg. Fahr., compared with water at the same temperature.

Pitch for Use in Wood Block as Adopted by New York City, 1914

The coal-tar paving pitch shall be a straight run residue obtained from the distillation of coal tar and shall comply with the following requirements:

(a) Melting point shall not be lower than 135 deg. Fahr. nor higher than 150 deg. Fahr. The contractor before beginning work on any contract shall obtain from the chief engineer in writing a statement as to the melting point desired for that particular contract and a variation of 5 deg. Fahr. either way will be permitted from this melting point, which, however, must be within the limits, as indicated above.

(b) Free carbon shall not be less than 22 per cent, nor more than 37 per cent.

(c) Specific gravity at 77 deg. Fahr. shall not be less than 1.24, nor more than 1.32.

(d) Specific gravity of the distillation to 670 deg. Fahr. shall not be less than 1.07 at 140 deg. Fahr. compared with water at the same temperature.

The tests governing the different elements are all closely interrelated and the attempt to change one without changing the others should not be made.

This is fully illustrated by Tables III and IV. Table III gives a series of refined tars made from the same raw tar, while Table IV gives three samples made from three tars of widely varying carbon content.

The tests used in these specifications and their significance have been given much study during the decade.

Table III

Sample No.	Free Carbon Percentages	Distillation Total to 315° C.	Melting Point, ° F.	Schutte Penetrometer, Sec. at ° F.		Viscosity Engler 100 c.c. at 100° C. Sec.	Float Test at 50° C Sec.
5	12.1	21.8	....	29	40	94	34
	12.0	19.2	....	108	40	127	38
8	14.0	16.4	....	114	50	159	58
9	14.4	14.9	86.9	85	60	208	75
10	17.2	12.7	99.7	90	70	335	110
11	18.2	10.4	108.7	88	80	431	170

Table IV—Relation of Viscosity to Carbon Content

Sample No.	Free Carbon Percentages	Melting Point, ° F.	Schutte Penetrometer at 80° F. Sec.	Engler 100 c.c. at 212° F. Sec.	Float Test at 212° F. Sec.
1	1.4	110	42.2	302	158
2	14.5	109	80.1	298	192
3	39.6	112	144.9	739	337

The specific gravity is of value as limiting to a certain extent the origin of the tar. The method used should be distinctly stated and the temperature at which the comparison with water is to be made should be given. Sixty degrees Fahrenheit is a usual temperature but many specifications call for 25 deg. C.

The viscosity or melting point is the most important test in the specification. It has nothing to do with the origin of the tar since any tar may be brought to a given viscosity or melting point above certain lower limits. It does, however, determine the way in which the material can be used and applied. In determining viscosity, the Engler viscosimeter is generally used for materials which are liquid at ordinary temperatures or which may be made fluid at the temperature of boiling water.

The float test or the Schutte penetrometer is often used for intermediate products while the melting point is generally specified for binders and fillers. Whatever method is used, the details must be specified in full.

The amount of free carbon desirable has been the occasion of much discussion. Practical experience in roofing and waterproofing work has shown indubitably the value of free carbon in pitches used for these purposes. In the case of road tars, it was argued that free carbon was an inert substance and could only be a diluent of the tar. A large number of experiments carried on to determine this point have seemed to indicate that tars very low in free carbon were too much affected by temperature and also more subject to change by weathering than tars which contain a fair amount of free carbon. At the same time an excess of free carbon is not desirable since it tends to make the material difficult to work. With cold surfacing materials, the free carbon must necessarily be kept lower, since its presence in considerable amount reduces the penetration of the material into the road surface.

The distillation test is important in defining the kinds of materials used in manufacture. It should always be coupled with a determination of the specific gravity of the distillate and the melting point of the residue.

The method of distillation should be specified with great detail. Unless this is done, the specification will be of little value since widely varying results may be obtained by different methods.

The development of suitable tars has gone hand in hand with the development of suitable specifications for their use and the development of suitable apparatus for their application to road surfaces.

The development of the whole industry has been a happy illustration of the importance of co-operation. The chemist, the civil engineer, the mechanical engineer and the manufacturer has each played his part. Any one, alone, could not have achieved the whole.

Society of Chemical Industry

Meeting of New York Section

The second meeting of the New York Section of the Society of Chemical Industry was held on Nov. 19 at Rumford Hall, Chemists' Building. Owing to the inclemency of the weather, the attendance was comparatively small, but in interest and liveliness of discussions the meeting was very successful.

Two papers on the program, by Dr. G. R. Fonda, on industrial argon and incandescent lamps, and by Dr. W. H. Walker, on chemical research in the iron and steel industry, had been withdrawn and a paper by Dr. Lewis, not on the program, had been substituted. This was first presented.

A FILING SYSTEM IN THE CHEMISTRY OF AMORPHOUS SUBSTANCES

The paper on this subject by Dr. **W. K. Lewis** of the Massachusetts Institute of Technology was of considerable interest and quite suggestive. This work is based upon the researches of the author as well as upon the researches of other chemists "on both sides of the water." All solids possessing desirable mechanical properties owe these properties to their amorphous condition. Such solids are plastic and can be molded without strain or fracture.

Thesis 1: All or nearly all amorphous solids are composed of large molecular aggregates.

Thesis 2: The molecular aggregates of most amorphous solids can be conceived as built up of a relatively small unit.

Thesis 3: Usually in an amorphous solid V_n the value of n is not fixed.

Thesis 4: The characteristic properties of all amorphous bodies are plasticity and relative inertness.

Thesis 5: The swelling of amorphous solids in solvents is due to the distension of an insoluble and impermeable residue by the osmotic pressure of a dissolved portion.

Thesis 6: Excessive mechanical manipulation of an amorphous solid ruptures the molecular aggregates.

Thesis 7: The utility of amorphous solids is due largely to their property of plasticity.

Numerous examples were cited to illustrate each one of the above seven theses. The author then took up methods of manipulation of plastics.

Method 1: By mechanical stress. The rigidity of the body is such that it will retain its molded shape without any further manipulation, *e.g.*, clay.

Method 2: Plasticity is secured by rise in temperature, rigidity is restored by cooling, *e.g.*, glass.

Method 3: Plasticity is secured by the action of a solvent, rigidity is restored by the removal of the solvent, *e.g.*, sugar.

Method 4: After manipulation of a plastic we may destroy the plasticity by chemical conversion into a new body less plastic, *e.g.*, ceramics, cement, plaster, etc.

Method 5: The plasticity may be lessened by increasing the size of the molecular aggregate produced by coprecipitation of two amorphous substances existing as colloidal solutions.

Method 6: In the complex V_n (amorphous solid) we can increase the size of the molecular aggregate by increasing n, *e.g.*, bakelite and all other condensation products.

Method 7: In the complex V_n we can increase the size of the molecular aggregate by increasing V, *e.g.*, rubber, linoxylin, oxycellulos, etc. In this case a small change in the unit V produces a great change in the plasticity and resistivity, *e.g.*, addition of sulphur to rubber (vulcanizing).

Those elements which do not combine chemically do not affect its plasticity. We also find that n in V_n decreases after rubber has been in solution, and more S is required to vulcanize rubber that has been in solution than the same rubber before it is dissolved.

Theories are a "filing system for facts," and in the manner sketched above many facts from the leather, starch and other industries may be explained.

In the discussion which followed, Dr. M. T. Bogert commented on the originality and novelty of the scheme proposed by Dr. Lewis.

RESEARCH IN CHEMICAL INDUSTRY

C. F. Burgess, president of the C. F. Burgess Laboratories of Madison, Wis., followed with a splendid paper, bringing out many fine points on a subject that some had thought had become somewhat stale for discussion —research in chemical industry. He started with a delightful little story of how his daughter had recently explained to an inquisitive elderly lady that "father used to be a professor in the University of Wisconsin, but two years ago he quit and got to work now."

Some of the points emphasized by Professor Burgess were as follows:

Twenty years ago the electrical engineering courses were most attractive to young men, but to-day chemistry gets their attention more and more.

Research work pays just as it pays to advertise.

Not all men are successful in research.

The research chemist and the manufacturer must ever be aware of the fact that there are more cases of disappointment than of success in research.

Many factories do not know how to conduct a research laboratory. Very often the laboratory becomes a mere adjunct to the sales department, and the unfortunate result is that the "research chemist" is eventually trained to get only such results in his tests, etc., as will boost the quality of the factory's product. Very often such results are far removed from scientific accuracy.

On the other hand, it is not advisable to separate the research laboratory from the sales department altogether. There ought to be an intimate contact between the two departments so that the research man will keep in touch with what is actually demanded.

The personality of the research man is a most important factor. Furthermore, proper training is essential; experience along mechanical lines is a great asset to the research chemist.

The manufacturer himself has to carry out the initial research work—when he selects the men for his research laboratory.

The average university graduate must give up some of his delusions, yet he must not lose his enthusiasm.

The problem of compensating a research chemist properly for his work is very important. To give a bonus to one man is often an injustice to another man. Further, the research worker must recognize the fact that there is a wide gap between research laboratory and factory when it comes to developing a process and putting it on a commercial basis. From his experience Professor Burgess concludes that when a product originally developed in the research department finally becomes a commercial product, the proportion of profits accruing from it which should be charged to the credit of the research department should usually be not more than 10 per cent. The other 90 per cent are due to members of the sales department and other departments. But a profit-sharing plan is difficult to work out.

The best way of taking care of the cost of equipment and maintenance of a research laboratory in a factory is to have a "development account" which might be entered as a fixed sum in the yearly budget.

ADMINISTRATION OF INDUSTRIAL RESEARCH LABORATORIES

Dr. **Raymond F. Bacon**, director of the Mellon Institute of Industrial Research, Pittsburgh, Pa., then presented in abstract an interesting paper of much originality on "some principles in the administration of industrial laboratories."

"Get your principles right, the rest is a matter of detail."

The proper selection of the director or controlling man is the real problem. He must be far-sighted and broad-minded, and must be of "peculiar normality." The direction of a research laboratory is very much like running a "zoo"—there are all kinds of animals with all kinds of tastes and habits.

In research work the unexpected results are often more important than those carefully planned and correctly predicted.

In a research man a pleasing personality is even more important than training or anything else. He must have "ginger and pep," and must be an "active optimist."

As regards the remuneration of the research man, this may be either a straight salary or it may be simply a bonus, or it may be a combination of salary and bonus. At the Mellon Institute the third scheme has been adopted. By bonus is meant a "small" cash bonus of, say, $2,000 to $5,000. Dr. Bacon does not believe in royalties or percentage bonuses.

A research man must be free from restraint and from petty annoyances. He ought not to hold an official position which does not permit him to devote his main energy and time to his research work. In the government institutions promotion to official positions is often a means of recognition, but this is a serious mistake.

Before starting a man upon a certain problem, the Mellon Institute makes it a practice to send the man to the factory which is interested in the problem, and there he remains until he is fully acquainted with the exact requirements of the problem.

The habit of reporting upon research work regularly once a week is very important. Not only do these reports form valuable records, but the man often realizes that he has not worked very hard during the past week. Accordingly, this system of reporting serves as a reminder and acts as a stimulus to do better work next week.

Dr. Bacon described at some length the remarkable equipment of the Mellon Institute. The methods of the Mellon Institute have met with great favor elsewhere, as the Royal Institute of Canada and the Sheffield Institute in England were modeled after the Mellon Institute.

GENERAL DISCUSSION ON RESEARCH

Dr. **A. M. Comey** of the Eastern Laboratory of the E. I. Du Pont Powder Company started the general discussion. He said that at their laboratory they find it absolutely necessary to keep routine work and research work separate and distinct. On the other hand, there is a real advantage in maintaining an amicable and intimate relation between the operating or manufacturing departments and the research laboratory.

In order to counteract any tendency of a feeling of jealousy to spring up among the members of the research laboratory they have found it necessary to make *one* man responsible for a certain problem or work.

The bonus system at the Du Pont laboratory has worked out very successfully. There are two kinds of bonuses:

Class A Bonus: For work that has brought material benefits.

Class B Bonus: For "zeal" where no direct material benefit accrues.

They train their own men at the laboratory by making them assistants or helpers, and they learn from their superiors. Sometimes it is found after a half a year or so that the man is not well suited for research work, and he is then transferred to one of the other departments, the analytical laboratory, the testing laboratory, etc.

When one of their men has made an improvement or an invention which is about to be carried out on a large scale in the factory, he is instructed to write up a detailed report and submit copies of this report—with his name attached—to various heads of the company. At times it is found advantageous to put the research man in charge of the process in the factory until it is fairly well established.

In a research chemist the combination of personality and common sense is more important than training. The man must be happy in his work and must not be hindered by time clocks and other strict regulations.

The remarks of Dr. Comey were heartily applauded. (The methods adopted by him and his company are usually conceded to be the nearest to the ideal. The laboratory has a splendid reputation.)

Dr. **C. G. Fink** of the Edison Lamp Works, Harrison, N. J., emphasized that an intimate relation between factory and laboratory is absolutely essential if the laboratory is to be of any direct value to the company. The head of the laboratory must realize at all times what the immediate and most urgent demands of the factory are and must be prepared at all times to render every assistance possible.

For example, when the European war deprived this country of potash and other raw material, it was necessary to find substitutes, and find them immediately. Thus soda glass was developed for potash glass for a certain special purpose. The factory usually cannot wait very long, and carefully planned research work covering periods of two, three or more years does not interest the factory. Many research men overlook this vital point in making an industrial laboratory an asset and a help. Give the factory "the next best" thing right off and then either improve upon it in the laboratory or find something better to take its place.

As to compensation, most factory heads do not appreciate the importance of giving the research men due recognition and credit for the work accomplished. "Usually a research man prefers proper recognition to an increase in salary or a bonus. He needs this recognition to keep up his enthusiasm. You cannot compensate a research man as you would compensate a salesman or a broker."

Dr. **A. D. Cushman**, director of the Institute of Industrial Research, Washington, D. C., said that they often find difficulty in getting sufficient financial assistance. "But on the whole we greatly enjoy our work. We look upon it as a most interesting game."

Dr. **J. B. F. Herreshoff** urged that in every laboratory there ought to be some men who have had business experience. Very often a young chemist will run into impractical lines. At their laboratories research has been going for very many years, only formerly instead of speaking of research they used to term it "improvements."

Prof. **M. T. Bogert** of Columbia University said that our industries must not overlook the importance of pure research work carried out at the universities. The investigation of new compounds and of complicated molecular reactions, etc., are problems fully as important as, if not more so, than the problems of the industrial laboratories. In this connection it is a source of gratification to learn of the establishment of the Willard Gibbs Professorship of Research in Pure Chemistry at the Mellon Institute. It is of vital importance to the

best interests of all that the industries assist the universities financially in carrying out research work in pure chemistry.

The meeting then adjourned.

The Physics of the Photographic Process*

BY C. E. KENNETH MEES

The unit of the photographic emulsion is the grain, and in order to study its properties we must study the properties of the individual grains. The grains are held in a sponge of gelatin, which is believed by Quincke to have a two-phase structure, one phase constituting the cell walls, and the other a solution filling the channels and cells themselves. Through these channels in the gelatin the migration of ions can take place at a velocity comparable with their diffusion rate in water, while penetration through the cell walls is a much slower and more difficult process.

Development consists of a reaction between an ion of the reducer and an ion of silver from the dissolved silver bromide, the silver ion being reduced to metallic silver in solution, which must then either precipitate or bring the reaction to an end. Precipitation can be induced only by the presence of a nucleus, and consequently in the absence of a nucleus for any grain, that grain will be undevelopable, the provision of the nucleus being the function of the "latent image." From a consideration of the energy required to produce a latent image in a high-speed photographic material it can be shown that the energy available per grain is of the same order as that required to ionize one molecule of a gas, and it is possible, therefore, that the latent image is composed of grains of silver bromide in each of which, on the average, one molecule has lost an electron by the action of light. The action of light on a photographic emulsion may, therefore, be classed as a photo-electric effect, and, as is the case with other photo-electric effects, the light must have a frequency above a certain critical value, the critical value depending upon the salt of silver employed, being about 400 $\mu\mu$ for silver chloride, and 480 $\mu\mu$ for silver bromide.

It seems probable that reversal is due to a slow decomposition of the silver bromide and liberation of bromine, which then attacks grains which had been exposed and contained a nucleus, rendering them undevelopable or, at any rate, less easily developable.

The size of the grain has several influences on the properties of photographic materials. In high-speed emulsions, if we assume that all the grains are equally sensitive, then the mass of silver produced for a given exposure will vary as the cube of the diameter of the grain, and the range of the sensitiveness experimentally found in high-speed emulsions can be accounted for by variation in the size of the grain without making any other assumptions.

It seems to be a fact that there is a qualitative difference between high-speed and low-speed emulsions, which must be due to the nature of the grains. If we start with a very fine-grained emulsion and cook it, the size of the grain and the sensitiveness will only increase to a certain limited extent, and in order to get a high-speed emulsion having larger grains and much greater sensitiveness, we must start in an entirely different manner, precipitating the silver of medium grain, which can then be increased in size with a concomitant increase of sensitiveness.

The difference may be that in the low-speed type the silver grains consist of a network of crystals containing gelatin, while in the high-speed emulsions the gelatin is distinctly separated from the crystals, so that in a low-speed emulsion each of the crystals forming part of the grain must be made developable by the action of the light, while the large grain of the high-speed emulsion requires action only at one point to make it entirely developable, the energy required to form a latent image in a high-speed emulsion being only that necessary for the liberation of one electron per grain, while in the low-speed emulsion several electrons for each grain may be necessary. Inasmuch as the grains of high-speed emulsions are not homogeneous in size, the sensitiveness will depend on the distribution of the grains of different size, and so also will the shape of the plate curve.

With a homogeneous emulsion we should have a simple curve with short over and under-exposure portion, but if the size of the grains varies more about the mean, then a curve having a longer straight line can be obtained, while any special distribution of the grains will be accompanied by a corresponding change in the shape of the plate curve.

The resolving power of an emulsion represents its ability to give sharp images and depends upon the side spreading of the light in the emulsion itself. It can be examined by printing images of the edge of a steel blade on the emulsion by parallel light, the distribution of the image inside of the shadow of the blade being afterwards investigated. It has been shown that there are three factors in the resolving powers: (1) The scattering power of the emulsion for light, (2) the absorption of scattered light by the emulsion, and (3) the photographic factor, which covers the reproduction of the light distribution as density distribution in the developed plate.

The distance between the two lines which will just be separated with a given emulsion will be extremely small for extremely small sizes of grain, because such sizes of grain far below the wave-length of light will scatter very little light; that is, the turbidity will be negligible. As the size of grain rises, however, the turbidity increases very rapidly, and with it the distance necessary to separate two lines, until with a grain diameter a little less than 1 μ the turbidity is high and the opacity still low, so that the necessary separation of the lines is a maximum, and then, as the grain still grows, the opacity grows faster than the turbidity and the lines to be separated can be somewhat closer together. Then, again, with the increasing diameter of the grains the actual space factor comes in, the size of the grains themselves and the distance between them becoming comparable with the distance between the separated lines, and with increasing size of grain this distance must again increase steadily.

Research Laboratory,
Eastman Kodak Company.

*From "Abridged Scientific Publications from the Research Laboratory of the Eastman Kodak Company, 1913-1914. This paper on the physics of the photographic process was originally published in the Journal of the Franklin Institute, 1915.

Recent Chemical and Metallurgical Patents

Tungsten and Zirconium

Treatment of Tungsten Ores.—A method of treating scheelite and its concentrates for the removal of phosphorus is disclosed in a patent recently granted to FREDERICK M. BECKET of Niagara Falls, N. Y. A representative sample of scheelite was found to contain 54.60 per cent WO_3, 3.45 per cent FeO and 0.212 per cent P. The ratio of tungsten to phosphorus was about 204. It is impracticable to eliminate this phosphorus by treating the ore with dilute acids without entailing serious loss of tungsten. The inventor has discovered, however, that if the ore is treated at red heat with concentrated sulphuric acid, the phosphorus is soluble while the tungsten is rendered nearly insoluble. The mixture of ore and acid is allowed to stand for some hours.

when the residue is washed until approximately free of sulphuric acid. By this treatment the tungsten-phosphorus ratio was increased from 204 to 3093 with a loss of less than 1 per cent of the total tungsten. The resulting product can be reduced by silicon to tungsten metal in the electric furnace; or it can be converted into ferro-tungsten by mixing with an ore of the iron-tungstate type, such as wolframite or ferberite, the mixture being proportioned to contain iron and tungsten in the ratio necessary to produce the desired alloy. This mixture is then reduced by silicon in the electric furnace. Thus the purified scheelite acts as a diluent of the less pure ores of the iron-tungstate type, and renders the latter available for the manufacture of low-phosphorus ferro-tungsten. (1,153,594, Sept. 14, 1915.)

Preparation of Tungsten for Lamp Filaments.—A method of treating metallic tungsten so that it will be specially suitable for the manufacture of lamp filaments is patented by Gottlieb Gmür-Zehnder of Aarau, Switzerland. The patentee has discovered that if tungsten is fused to a perfectly liquid condition in an electric furnace and then cooled rapidly it will be exceedingly fine in granular structure and perfectly malleable and ductile. The furnace is of the resistance type and the tungsten is heated by radiation. The cooling is accomplished by a blast of cold compressed air. (1,150,670, Aug. 17, 1915.)

Zirconium-Iron Alloy for Lamp Filaments.—Attempts hitherto made to produce commercially useful alloys of zirconium have not been very successful, as the brittleness of the metal has characterized its alloys. Moreover, it has been found extremely difficult to produce alloys of the metal by direct combination with other metals. According to a patent granted to John L. Brown of Baltimore, Md., however, it has been found possible to produce satisfactory alloys of zirconium and iron and other metals by reducing mixtures of compounds containing these metals. The alloys thus produced are of a type hitherto unknown among metallic zirconium combinations. They exhibit little tendency to oxidize and are resistant to most chemical reagents. They are also tough, malleable and ductile. The value of these alloys for lamp filaments is that they have the property of selective radiation and possess a remarkably high degree of luminescence at relatively low filament temperatures. The presence of titanium, aluminium, tantalum, and columbium give alloys that offer certain advantages for special purposes. (1,151,160, Aug. 24, 1915.)

Gold and Silver

Agitator.—A type of mechanical agitator for slime pulps is shown in Fig. 1, being the patented invention of Albert E. Vandercook of Alameda, Cal. In this agitator the pulp is circulated by means of a centrifugal pump 32 through a vertical stationary pipe 2 and radial movable arms 17, the intake to the pump being by way of pipe 31. The principal feature of the agitator is the construction of the gland 13, which forms the rotatable part of the bearing, whereby pulp is prevented from finding its way into the ball race. As the movement of the radial arms, due to the discharge of pulp through the nozzles 18, is not visible, an indicating rod 27 is attached to a boss on the gland, thus indicating the motion of the rotating element. (1,156,946, Oct. 19, 1915.)

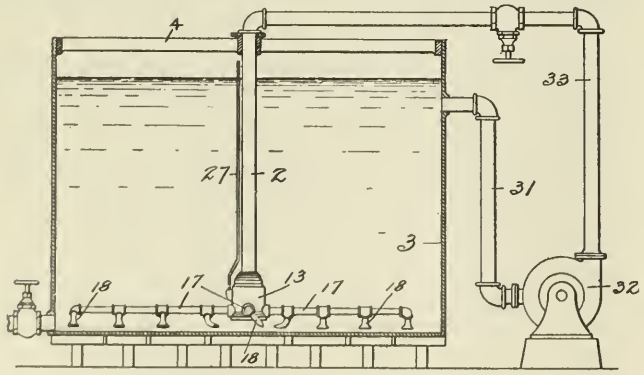


FIG. 1—AGITATOR

Copper

Copper Converter.—In the ordinary type of converter construction the gases are discharged through a throat in the upper side of the shell; and since the hood which directs the gases to the flue is stationary, it has an unduly large opening in order to cover the range of the converter when it is set at varying angles. This arrangement permits the entrainment of a great amount of air into the flue, from two to three times the quantity of gases discharged from the converter. As an improvement on this construction, William H. Howard of Garfield, Utah, has patented a form of converter

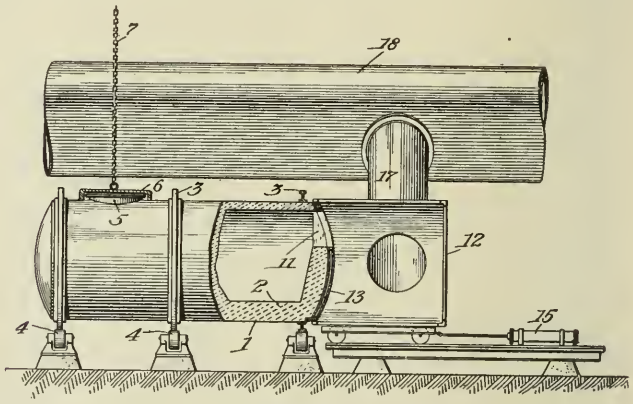


FIG. 2—COPPER CONVERTER

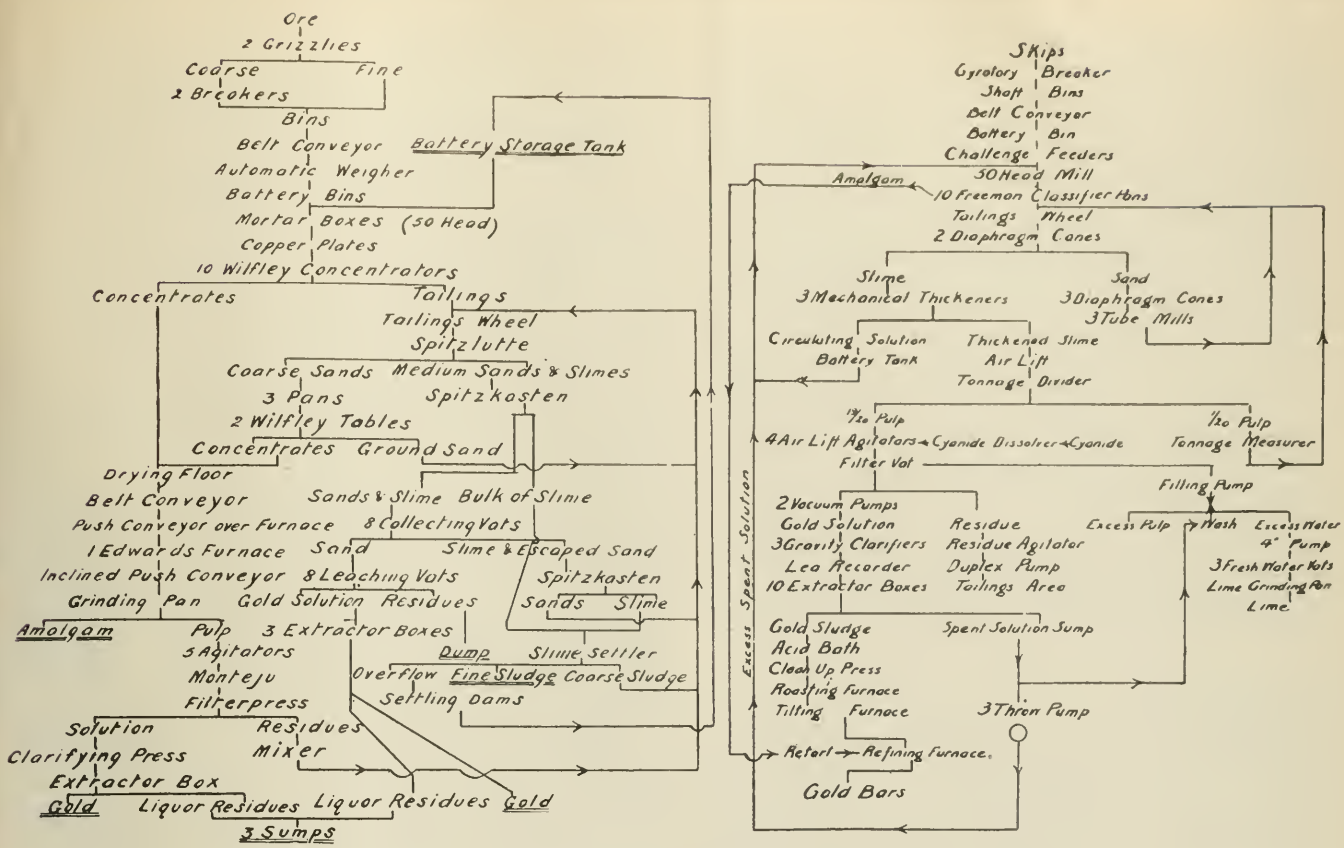
with adjacent stationary hood, as shown in Fig. 2. The converter has its discharge opening at one end and is combined with a stationary hood concentric with the shell of the converter and telescoping that end in which the discharge opening is placed. By this construction the exit for gases is always within the hood, regardless of the position of the converter shell. In Fig. 5 the converter is shown with a lining 2, a covered opening 5 for introduction of matte, waterjacketed end 13, and exit for gases at 11 into the hood 12, which communicates with the flue 18 by pipe 17. Spouts for pouring slag and metal and tuyeres are not shown. A practically tight connection is maintained between the converter and the hood, thus insuring the delivery into the flue of substantially undiluted gases. (1,153,921, Sept. 21, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Wood-Burning Assay Furnaces.—By the substitution of wood for coke and charcoal, and the reconstruction of the assay furnaces to give conditions suitable to burning wood, H. R. Edmands effected a saving of about £12 or nearly $60 per month. The furnace is illustrated and described in the monthly *Journal* of the Chamber of Mines of Western Australia for May, 1915.

The furnace used for fusions is a reverberatory of the type described by McArthur Johnson in "Rand Metallurgical Practice." The firebox is 19 in. wide, 28 in. high and 30 in. deep. The hearth behind the bridge takes the place of the ordinary muffle, and is covered



FIGS. 1 AND 2—FLOW-SHEETS OF 1906 (AT LEFT) AND 1914 (AT RIGHT)

with sand to absorb any slag that may boil over from the crucibles placed thereon. The hearth is covered by a firebrick arch, and an opening at the side is used for placing and removing crucibles. For cupellation a wood-burning muffle furnace is used. The average life of crucibles and muffles is much greater in these wood-burning furnaces than in either coke or charcoal furnaces. Fuel consumption for both furnaces is about 6 tons of wood per month, costing £3 6s. Previous cost of coke and charcoal for the same work was £13 11s., or a saving of £10 5s. per month, to which must be added the saving in crucibles and muffles, amounting to about 35s., or a total saving of £12.

Cyaniding at the Sons of Gwalia, Australia.—The accompanying flow-sheets, Figs. 1 and 2, taken from the monthly *Journal* of the Chamber of Mines of Western Australia, illustrate the simplification of cyanide treatment at the Sons of Gwalia mine. Explanatory data are contributed by Mr. A. WAUCHOPE. The former system consisted in wet crushing, amalgamation in mortar boxes, followed by pan grinding, table concentration, vacuum filtration of slime and leaching of sand. Experiments having demonstrated that all-sliming would be as effective as double treatment, the mill was remodeled on that basis, as shown in Fig. 2.

In the present scheme no amalgamation is done in mortars or on plates, but in 5-ft. Forwood Down grinding pans with Freeman selective pipe discharge. About 20 per cent of the gold is recovered here, with a mercury consumption of 0.23 oz. per ton of ore crushed. Tube-mills have corrugated hard-iron liners, with flint pebbles as the grinding medium. The pebble load for each 18-ft. by 4½-ft. tube is 7 tons, and the consumption is about 1.5 lb. per ton of ore crushed. The slime product contains about 10 per cent of material coarser than 150 mesh. Continuous mechanical thickeners discharge a pulp of 45 per cent moisture which is agitated continuously by combination mechanical and pneumatic agitators. The filter is of the Cassell type, with forty-four leaves each 9 ft. by 5½ ft. The cotton-duck cloths have a life of about six months, the long service being attributed to a softening of all water taken into the plant. The softening process prevents a precipitation of magnesia when water is mixed with plant solutions. Wet vacuum pumps maintain a vacuum of about 25 in. during filtration and 7 in. during pulp transfer. The elevation is 1400 ft. above sea level. In order to prevent cracking and falling of cakes during changes of pulp and wash solutions, a number of sprays drench the cakes with atomized solution which not only washes the sides of the tank and prevents salting of the following wash, but also reduces loss of dissolved metals. Solution tonnage is measured by means of a Lea V-notch recording meter, which has proved satisfactory over a period of eight months and has permitted close regulation of operations. Solution is precipitated on zinc shavings in boxes having a capacity of 0.8 cu. ft. per ton of solution per day. One and a half tons of solutions is precipitated per ton of ore crushed. The gold-zinc slime is acid-treated, filter-pressed, roasted in a wood-fired reverberatory furnace, and smelted in a tilting, coke-fired furnace. The consumption of chemicals per ton of ore is: KCN, 0.45 lb.; Zn, 0.37; CaO, 3.4; H_2SO_4, 0.2.

Metallurgical Practice on the Rand, South Africa.—A review of the development of gold metallurgy in South Africa was given in a paper before the American Institute of Mining Engineers at San Francisco by F. L. BOSQUI, covering two periods, that preceding the use of cyanidation on a commercial scale in 1890, and the twenty-four years subsequent to that important event. Cyanidation was introduced as a result of trials at the Salisbury battery in 1890 by the Cassel Gold Extraction Co. The first application on a commercial scale was in the same year, when the Gold Recovery Syndicate treated by contract 10,000 tons of tailing on the prop-

erty of the Robinson Gold Mining Co. The Siemens-Halske electrolytic method of gold precipitation was introduced in 1894 at the Worcester mine and was adopted at several other properties, but never won general acceptance owing to the delicacy of the process and the formation of troublesome by-products. It was finally abandoned in 1898 in favor of zinc. With the reversion to the use of zinc, Rand metallurgy may be said to have crystallized into a general scheme of milling and of separate treatment of sand and slime by cyanide. Even the introduction of tube mills in 1904 did not seriously modify the main features, the tube becoming an accessory to the stamp. The vacuum filter was introduced in 1909. The fact that local practice has not adopted numerous processes found feasible elsewhere is not a reflection on the lack of enterprise of Rand metallurgists, but rather of their knowledge of local conditions requiring simplicity in operation, low maintenance and treatment cost, and high efficiency. The ore is low-grade, ranging from 4½ to 9 dwt. gold per ton, up to 70 per cent of which is amalgamable. The author gives the following tabulation of variations in local practice as adopted at different mills:

Step in Treatment	Variations
I. Ore sorting and breaking.	(a) Ore washed in trommels or in stationary chutes.
	(b) Ore sorted on slowly moving belts or on revolving tables.
	(c) Ore broken in two types of crusher, those in common use being the Blake swinging jaw type and the Gate gyratory.
II. Stamp-milling	(a) A range in weight of stamps from 1,150 to 2,000 lb.
	(b) Considerable variation in details of battery construction; also variation in mesh of battery screen dependent chiefly upon tube-mill facilities.
III. Amalgamation	(a) Use of battery plates, and so-called tube-mill plates for secondary amalgamation after tube milling.
	(b) No battery plates; all amalgamation done after tube milling.
	(c) Tube-mill plates, shaking and stationary.
	(d) Considerable variation in ratio of area of plates to tonnage.
IV. Tube milling	(a) Tube mills of varying dimensions.
	(b) Varying ratio of number of tube mills to stamps.
	(c) Devices for thickening pulp and feeding tube mills.
	(d) Kinds of "liner" in use.
V. Classification of pulp	(a) Coarse sand separated out and sent to tube mills.
	(b) Separation of sand from slime.
	(c) Classification in spitzkasten or hydraulic cones.
VI. Treatment of sand	
1. Collecting	(a) Collecting tanks superimposed on treatment tanks, or on ground level, and fed by (1) movable hose, (2) Butters and Mein distributors.
	(b) Collecting tanks filled direct from classifiers or with solution-borne pulp from Caldecott sand-filter tables.
2. Treatment	(a) Sand dropped from superimposed collectors into treatment tanks.
	(b) Sand transferred by belt conveyor from collectors on ground level.
	(c) Sand collected and treated in the same tank from Caldecott sand-filter tables.
	(d) Sand residue trammed to dump in trucks.
	(e) Sand sent to dump by aerial bucket conveyor.
VII. Treatment of slime	(a) By circulation with pumps and decantation.
	(b) By agitation in Pachuca tanks, followed by filtration with Butters vacuum filter.
VIII. Gold precipitation	(a) On zinc shavings.
	(b) On zinc dust in Merrill presses.
IX. Smelting methods	(a) In Travener lead furnaces, with cupellation.
	(b) Direct smelting in pots.

Speaking of the introduction of the Nissen single stamp, the author says that, pound for pound of dropping weight, the Nissen stamp will crush about 30 per cent more rock per day with an increased efficiency of 35 per cent over the ordinary stamp. He sums up the distinct advantages of the single-stamp principles as follows:

1. Owing to the mortar being circular, the screen can be extended around the stamp for the greater part of the circumference of the mortar, so that it is equally distant from the stamp throughout its full length. The screen is therefore always at right angles to the direct splash of the pulp, in the most advantageous position.

2. At each blow of the stamp the pulp is forced radially against the screen, so that all particles sufficiently reduced are discharged. Owing to the mortar box being circular, each time the stamp is raised all the material in the mortar flushes to the center, to be struck by the falling stamp. It follows, therefore, that the uncrushed ore is automatically returned to the crushing zone, so that the best conditions of feed are maintained.

3. The blow being always received in the vertical axis of the box, the mortar remains rigid on its foundation. This is noticeable in the case of the Nissen stamps at the City Deep, where, after three years of use, the box is apparently as rigid on its base as on the day it was fixed in position.

4. One of the important features of the Nissen box is that it can be cast with a minimum likelihood of shrinkage strains, which are so destructive to ordinary 5-stamp mortars. The foundation bolts give no trouble, not being subject to undue strains.

5. Another advantage of the unit principle is the more continuous operation and flexibility of the entire plan, as each stamp can be put out of commission independently.

6. An interesting feature of this type of stamp is the comparatively even and flat wear of the dies, which results from the return wash of the ore to the center of the mortar with each stroke of the stamp, and from the increased number of rotations of the stamp due to wider cam and tappet faces.

With regard to tube milling, it is now generally accepted that a battery product through a screen of 0.272-in. aperture is about the economic limit of size for tube-mill feed. Beyond this limit the tube encroaches on the domain of the stamp. The proper ratio of tubes to stamps is variable, but in recent practice the tendency is to have a ratio of one 22-ft. 6-in by 5-ft. 6-in. tube to ten 2000-lb. stamps, or one tube to 200 to 250 tons per day of product of the size given above.

Referring to the development of the principle of peripheral discharge from tube mills, the author gives the following conclusions deduced from tests:

1. That when maintaining the pebble load at the center mark with feeds ranging from 250 to 400 tons per 24 hr., a 25 per cent increase in crushing efficiency could be obtained, but with proportionately increased power consumption.

2. That within certain limits of feed, the weight of the pebble load can be decreased by 25 per cent without affecting the crushing efficiency, with about a 10 per cent decrease in power consumption, the mechanical efficiency showing a corresponding increase.

3. That the wear on the crushing load is increased 300 to 400 per cent.

4. That by decreasing the effective radius of the scoop from the maximum possible (about 29 in. in a 5 ft. 6 in. mill) to the ordinary trunnion discharge, a steady decrease in crushing efficiency is accompanied by a proportionate decrease in power consumption.

Vacuum filtration is now generally conceded to be applicable where it is desired to extend a decantation plant of inadequate capacity or obsolete design; where difficulty in settlement makes it impracticable to use decantation without prohibitive extension of plant, and in all new plants.

Zinc dust precipitation has been adopted at some mines, and offers some distinct advantages over zinc shavings. The following details cover three months' operation at the Brakpan.

	Tons Precipitated (Average per Day)	Gold Content of Dwt.	Gold Content of Dwt.	KCN Content Inflow, per Cent	KCN Content Outflow, per Cent	Alkalinity (CaO) Inflow, per Cent	Alkalinity (CaO) Outflow, per Cent
Sand solution	269	3.952	0.045	0.070	0.036	0.023	0.027
Medium sand solution	769	1.548	0.056	0.017	0.009	0.0146	0.015
Slime solution	1791	1.271	0.048	0.010	0.007	0.0149	0.015

The consumption of zinc in the Merrill presses is approximately 1/10 lb. less than in boxes. At Johannesburg zinc shavings cost 4.2d. per pound and zinc dust 3.93d. ($0.084 and $0.0786 respectively). The lower cost of dust is offset by the greater strength of cyanide solutions required for good precipitation. The general opinion is that the zinc dust method is effecting economies in zinc consumption and labor and in affording a complete clean-up of gold.

Percentage extraction has increased from 60 per cent in 1890 to a maximum of 96 per cent in 1914. The cost of reduction of Rand ores ranges from $0.68 to $1.20 per ton milled. Figures for the Modderfontein B are given below:

COST OF TREATMENT AT MODDERFONTEIN B.—NOVEMBER, 1914. 42,000 TONS MILLED

	Per Ton Milled, Cents
Ore sorting and breaking	5.3
Transport from crusher station to mill bins	0.7
Stamp milling	17.5
Tube milling	12.5
Amalgamation	3.6
Cyaniding	29 0
Total	68 6

Amalgamation Tests.—A discussion of the various proposed methods for estimating the gold content of ores by amalgamation, together with a proposed standard method by the author, W. J. SHARWOOD, formed the subject of a paper at the meeting of the American Institute of Mining Engineers in San Francisco. Twenty-six published methods are reviewed and the following standard amalgamation test suggested:

Equipment Required for Systematic Amalgamation Tests

Agitator. A shaking box, stoutly built, with twenty-four or more compartments, each 3 in. square and 6 in. deep, driven from a shaft running about 250 r.p.m., giving a horizontal travel of about 2 in. The entire bottom, or each section, should be covered with heavy belting or linoleum.

Twenty-four "citrate magnesia" bottles, with spring clamps and rubber washers. These have a capacity about 350 to 370 cc.

Twenty-four Griffin beakers, capacity about 250 cc.

Two enameled-iron pans, rectangular, with straight sides, to hold twelve beakers each.

Filtering rack with twelve 2¾-in. funnels and twelve extra beakers.

Hot plate.

Glass-stoppered burette for pure mercury, standing over an enameled pan.

Robervahl scale, turning with ½ g.

Cylinder, graduated to 100, 150, and 200 cc.

Weighing scoop and steep-sided copper funnel or hopper for charging ore into bottles.

Six-inch funnel for water.

A few porcelain dishes about 3 in. diameter, and some enameled pans about 8 in. diameter and about 2 in. deep.

Filter paper, 12.5 cm., S. and S. No. 595 or similar quality.

Scorifiers, 2 in. or less in diameter; these may be used repeatedly and are best glazed before first using.

Washbottle.

Test lead.

Nitric acid, diluted with about double its volume of water.

Mercury, pure or previously assayed.

Silver foil, cut in pieces of about ½ g. each.

Routine Method for Gold Only

One hundred grams of crushed ore or tailing are weighed out, charged into a bottle by means of the metal funnel, 150 cc. of water added, then 1.5 to 2 cc. of pure mercury from a burette. The stopper is then clamped, the bottle folded in a thick piece of cloth or flannel and put into the moving "shaker" for 2 hr. It is then removed, opened, covered with the thumb, shaken and inverted over a 3-in. porcelain dish, and as much as possible of the clean mercury allowed to run out. It is then shaken again for a moment, and if necessary a little more water is added, and more mercury allowed to run out into a second dish, and so on, as long as any mercury comes out. If not floured the mercury is nearly all removed in two operations. The clean mercury thus obtained is transferred to a beaker. The bottle is again shaken well and inverted so as to let a little sand run out into the dish; this is then panned into an enamel dish. Usually only a few globules are obtained; if much is found the whole charge must be panned. If "floured" a small globule of liquid sodium amalgam should be added at this point.

To the mercury, after collecting in a 250-cc. beaker, is added ½ g. of pure silver foil. If this has been carefully prepared and cleaned by treating with cyanide solution or weak nitric acid, or by slightly amalgamating the surface, it may be used to pick up the small globules of mercury obtained in panning. About 150 cc. of nitric acid (sp. gr. 1.14 or 1.15) previously warmed to about 70 deg. C. is now poured into the beaker; all the beakers are set together in a pan, which is placed on the hot plate and left until all the mercury has dissolved. If not too hot it is unnecessary to use covers. As soon as the mercury disappears the liquid is filtered, the residue is rinsed on to the paper, washed once or twice with very dilute nitric acid (not over 5 per cent) and once with water. The paper is then sprinkled with test lead, folded, and placed in a small glazed scorifier, and covered with lead enough to make up the total to 15 or 20 g. Enough pure silver is added to insure ready parting, and 2 or 3 g. of borax glass. The scorifiers are then charged into a muffle, the paper carefully burned, the lead scorified a few minutes, poured, and cupelled. The cupel buttons are parted in porcelain cups, and the gold annealed and weighed.

A correction is subtracted for gold contained in the silver and mercury.

Using a 100-g. sample, each milligram of gold represents 0.29166 oz., or $6.03 amalgamable gold per ton.

The author suggests that if assay tons are used, each milligram indicates exactly 0.25 troy ounce, or 120.5 g./ when each milligram indicates exactly $5 per ton. The ore should be ground quite fine, 100-mesh being found suitable.

A Rule Governing Cupellation Losses.—A paper by W. J. SHARWOOD giving an empiric rule by which cupellation losses of silver or gold can be calculated and a correction applied. The rule is thus stated:

When a given amount of silver (or of gold) is cupelled with a given amount of lead, under a fixed set of conditions as to temperature, etc., the apparent loss of weight sustained by the precious metals is directly proportional to the surface of the button of fine metal remaining.

If the above is true the following also must be true:

The loss of weight varies as the 2/3 power of the weight, or as the square of the diameter of the button.

The percentage loss varies inversely as the diameter of the button, or inversely as the cube root of the weight.

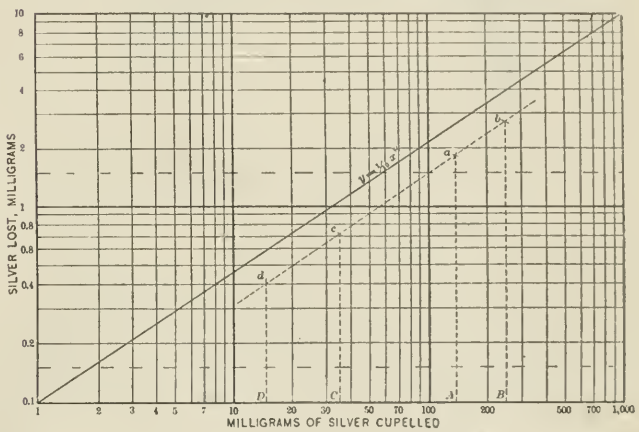


FIG. 3—CUPELLATION DIAGRAM

The author states that the examination of a large number of experimental results proves the last statement to be a close approximation to the truth, and therefore proof of the others.

"The readiest proof of the rule, which avoids all calculation, is by the aid of logarithmic paper—that is, paper on which the co-ordinates are plotted on a scale like that of a slide rule. In place of using the ruled paper the distances may be actually laid off by means of a slide-rule scale.

"As to the possible application of this rule: An approximate correction may be obtained for an ore or the like, if one proof, as near the expected weight as possible, is cupelled in each row, and its exact loss noted. The corresponding point is plotted on the diagram (*a* in Fig. 3, *A* representing the final weight), and a straightedge is placed on the diagram, or a line drawn through *a*, parallel to the guide line, $y = x^{2/3}$. Noting the points on the line or straightedge corresponding to the weights *B*, *C*, *D*, of other buttons weighed, the correction for each is read at once from the scale. In the example plotted in Fig. 3, a button of 140 mg. weight has lost 1.8 mg.; from this it appears that other buttons of 250, 35, and 15 mg. will respectively have lost about 2.85, 0.72, and 0.40 mg."

Improved Apparatus for Photomicrography of Metals

The chief characteristics of an efficient photomicrographic apparatus are rigidity, firmness, compactness, brilliant and uniform illumination, accuracy of detail in the photograph of the structure under examination, quickness and ease of manipulation.

These essentials are embodied in the improved photomicrographic apparatus, illustrated in Fig. 1 and designed and supplied by Sauveur and Boylston, Metallurgical Engineers, Cambridge, Mass.

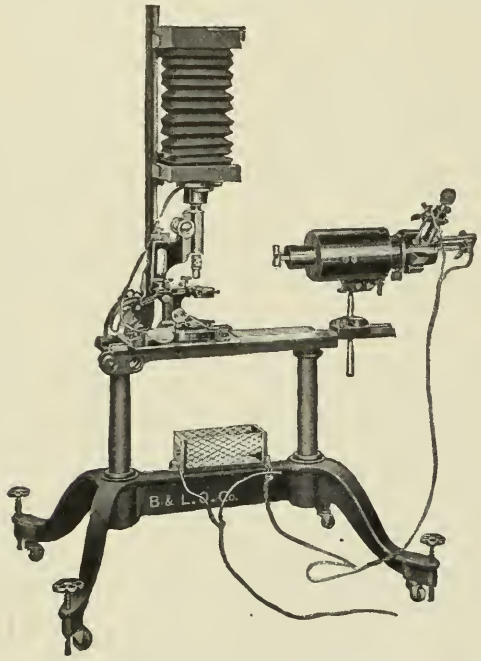


FIG. 1—STANDARD PHOTOMICROGRAPHIC APPARATUS; ABOUT 1/20 ACTUAL SIZE

Rigidity.—In many works laboratories vibrations are present from one cause or another. The different parts of the apparatus described here are rigidly clamped together so that the apparatus vibrates as a whole thus obviating the fuzzy or blurred detail so often obtained with other instruments especially at high magnifications.

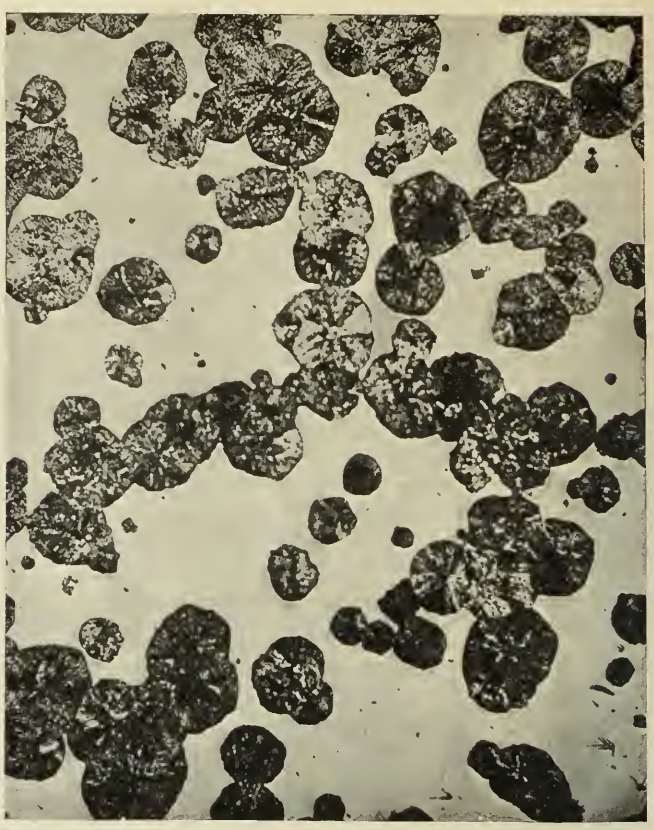


FIG. 4—MICROSTRUCTURE OF QUENCHED HIGH-CARBON STEEL (ROSETTE OF TROOSTITE ON LIGHT BACKGROUND OF MARTENSITE MAGNIFIED 150X) TAKEN WITH APPARATUS ILLUSTRATED IN FIG. 1

Firmness.—The heavy construction of all parts of this apparatus makes for firmness, which in turn means simplicity in adjustment of parts such as the microscope, camera, and arc lamp adjustments.

Compactness.—One of the chief faults of older types of instruments of this sort and of some recent types is a tendency to spread out the apparatus over a large floor space. In this instrument the carbon adjustments and those of the condenser are easily accessible to the operator who is seated in front of the microscope for visual work (see Fig. 2). When taking a photograph the operator simply rises and without moving from the spot can focus the image on the ground glass of the camera in a standing position as shown in Fig. 3. This feature will be readily appreciated by those who have worked with the less convenient or larger apparatus.

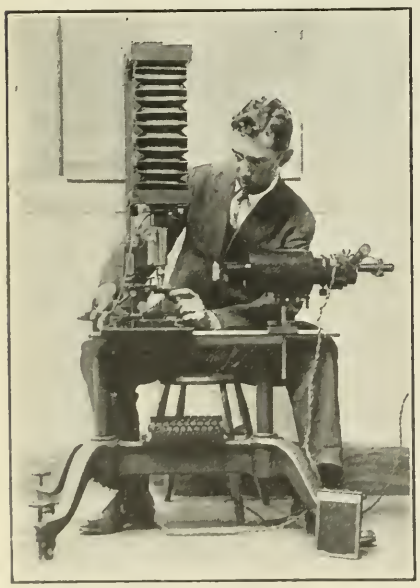


FIG. 2—PHOTOMICROGRAPHIC APPARATUS WITH OPERATOR SEATED

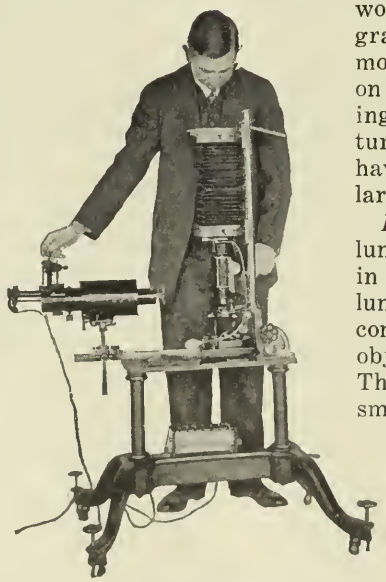


FIG. 3—PHOTOMICROGRAPHIC APPARATUS WITH OPERATOR IN POSITION FOR FOCUSING IMAGE AT CAMERA

Illumination.—Brilliant and uniform illumination of the specimen is brought about in the usual way by the use of a vertical illuminator of the plain glass reflector type in combination with long-mounted achromatic objectives of Bausch & Lomb manufacture. The source of illumination may be either a small arc lamp consuming 4.5 amp. or a 250-watt nitrogen-filled Mazda lamp of special design in light-tight lamp box with the necessary lateral and vertical adjustments for the lamp as a whole. Either lamp may be used on an ordinary house circuit.

Accuracy of Results.—Photomicrographs shown in Figs. 4 and 5 magnified 150 and 400 diameters respectively will give some indication of the accuracy

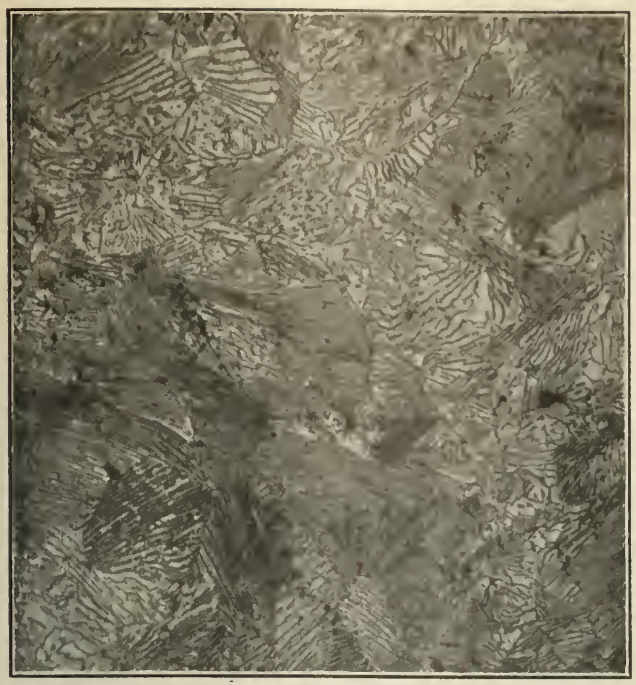


FIG. 5—MICROSTRUCTURE OF PEARLITE (MAGNIFIED 400X) TAKEN WITH APPARATUS ILLUSTRATED IN FIG. 1

of detail in the structures photographed with this apparatus. These photomicrographs were obtained with the aid of a green monochromatic ray filter regularly supplied with the apparatus together with orthochromatic plates. The use of this screen and plate in combination with achromatic objectives of great flatness of field such as are furnished with this outfit renders the use of expensive and fragile apochromatic objectives of doubtful value.

Speed of Working.—With the green ray filter, orthochromatic plates, and achromatic objectives used in connection with the 4.5 amp. arc lamp on an alternating-current circuit the photographic exposures necessary range from seven to twelve seconds at 100 diameters and from thirty to sixty seconds at 1000 diameters depending upon the contrast in the structure of the specimen. With direct current these exposures are reduced about 30 per cent while with the Mazda lamp the figures given above should be multiplied by 1½ or 2. As many as eighty photomicrographs at 100X have been taken, developed, and fixed in an eight-hour day by one operator using one of these instruments.

The Microscope.—This part of the apparatus is the same in general design as that used by Professor Sauveur as far back as 1892, but with improvements in the mechanical and optical details from time to time which have brought it up to its present standard. The microscope as now furnished includes Sauveur vertically-movable stage for coarse adjustment with the latest Bausch & Lomb lever fine adjustment and mechanical stage. An improved form of magnetic specimen holder* has bevelled edges, which allow the close approach of a high power objective to a specimen without the necessity of a templet or other auxiliary device. Specimens measuring from ⅛ in. or less in diameter up to 1 in. in diameter can be easily examined by the use of this magnetic holder, which is illustrated in Fig. 6, or by means of the bridge type of specimen holder designed by Sauveur in 1892 and illustrated also in Fig. 6. The microscope has a body tube of 1½ in. diameter, which increases its usefulness when very low power photomicrographs are being taken and the new construction of the stand gives a very long working distance between the objective and the stage. For the examination of very large specimens, such as rail sections, etc., an auxiliary tube is provided, the specimen being placed across the horseshoe base of the microscope.

The Camera.—This is generally furnished to take 5 x 7 plates or smaller, and a 4 x 5 camera can be supplied if desired. The camera is fitted with automatic shutter with Iris diaphragm.

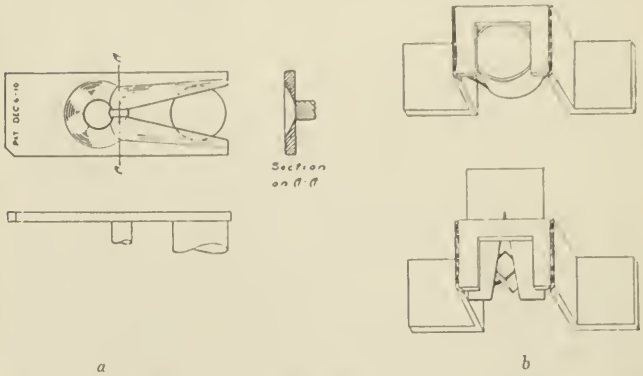


FIG. 6—*a*, MAGNETIC SPECIMEN HOLDER WITH LARGE AND SMALL SPECIMENS; *b*, NON-MAGNETIC SPECIMEN HOLDER WITH LARGE AND SMALL SPECIMENS

Range of Usefulness.—This apparatus may be used not only for the photomicrography of all kinds of metals and alloys, but also in the case of other opaque objects such as ores, rocks, concrete, slags, wood, leather, paints and varnishes, rubber, etc. The lamp may also be tilted at an angle for use with oblique illumination for opaque specimens, including core and molding sands, and with transmitted light for the examination and photomicrography of transparent sections.

The apparatus is wholly American-made and of moderate price.

*Patented Dec. 6, 1910.

Thermit Welding of Camshafts

Experience with thermit welding of camshafts at the Belmont mill, Tonapah, is given by the superintendent, A. H. Jones, in his paper read at the meeting of the A. I. M. E. at San Francisco. Two shafts were welded at the following cost per shaft:

Labor	$16.00
85 lb. thermit	21.60
Iron punchings	0.38
Wax	1.75
Gasoline (preheat)	2.80
Total	$42.53

The first shaft repaired was put into service July 1, 1914, and broke, in the weld, Aug. 8, 1914. The second was put into service Aug. 8, 1914, and broke, in the weld, on Sept. 13, 1914. These two shafts were welded at the break, necessitating their being turned down to original size, which is against the advice of the "thermit" manufacturers. On April 6, 1915, another shaft was welded from two long, discarded ends, sawed so that the weld would come in the middle box, and a boss ½ in. high and 4 in. wide left, which was taken care of in babbitting the center bearing. This shaft is still in service and may show a life really worth while. Figuring 8.88 tons per stamp day, the 30-day service from the first two shafts welded would cost about 2c. per ton of ore stamped, which, in case of breakage with no spare at hand, would be better than having ten stamps out of commission for any length of time, and therefore thermit supplies are kept on hand for this and other emergencies.

New Flotation Testing Machine

The widespread interest that has been aroused in the flotation process of concentration has created a demand for simple and efficient means of making tests on small lots of ore with different oils and oil mixtures. To meet this demand the Denver Fire Clay Company of Denver, Col., has designed the flotation testing unit illustrated in Fig. 1. Neat in appearance, compact and well constructed, it presents a marked contrast to the home-made testing apparatus with which many investigators have had to content themselves.

The Case machine consists of a single aluminium casting comprising the agitation cell and spitzkasten, mounted on a heavy board which also carries a bracket for the support of the propeller shaft and a shelf for the motor. Connection between the bottom of the spitzkasten and the agitation cell, for circulation of pulp, is made of rubber tubing which is readily removed for cleaning the apparatus. The propeller blade is made of aluminium, while the steel shaft is coated with lead in order to resist the attack of the acid that may be used in the process. The motor is a $\frac{1}{8}$-hp. Westinghouse machine operated from a 110-volt circuit at 1800 r.p.m. Variable speed of the flotation propeller is provided for by a three-speed pulley which will give approximately 1800, 1600 and 1400 r.p.m.

The entire apparatus stands about 4 ft. high and can be attached to the wall or other support convenient to a water supply. Accessory apparatus has been prepared for use with the machine, in the form of a metal hoe or scraper for removing the froth as it forms, and ground-glass-stoppered dropping bottles for measuring the quantity of oil used. The machine will prove a timely and welcome addition to the laboratory of the metallurgical investigator. A recent modification of the type shown in the illustration has only a single-speed pulley on the driving shaft and a variable-speed motor. This combination is thought to offer some advantages.

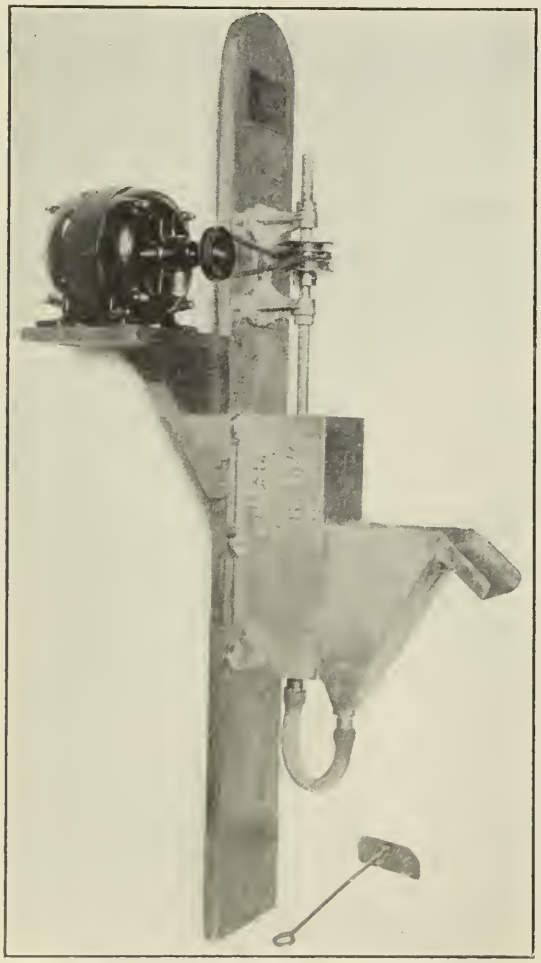


FIG. 1—FLOTATION TESTING MACHINE

Sampling Lead Bullion

The methods of sampling lead bullion at Salida, Col., and El Paso, Tex., are given in the following extracts from papers appearing in Bulletins of the A. I. M. E.

According to Mr. F. D. Weeks, an early method of sampling at Salida was to take a dip from the lead well of the furnace, but this was not satisfactory. The present management built drossing kettles in which the bullion is stirred by compressed air, skimmed into a Howard press, stirred by hand and siphoned out into bars for shipment, after sampling by dipping "gum-drops," approximately $\frac{1}{2}$ assay ton in weight. For some time the results were unsatisfactory. Although the copper had been reduced to 0.06 per cent, the bullion had a dirty appearance, and "gum-drops" of the same dip would not check with each other, especially as gold content. Consultation with men versed in the subject did not help. A remedy was finally found when the temperatures were determined by a pyrometer and the difficulties overcome by the following procedure: Take off heavy dross at 900 deg. Fahr.; blow until temperature reaches 680 deg. Fahr., skimming from time to time; raise the heat to 720 deg. Fahr. for sampling, and mold at 800 deg. Fahr. Since this method was adopted, little trouble has been encountered.

A plan to eliminate the personal equation in bullion assaying has been carried out for some years, with good results. The "gum-drops," weighing about $\frac{1}{2}$ assay ton each, are weighed without trimming, cupelled, and parted; the weights of the "gum-drops" in decimals of an assay ton, of the gold and silver together and of the gold alone, in milligrams, are reported by the assayer. The calculations are then made in the office on a machine. In this way the assayer is not tempted to make his results check, because until they are figured he does not know whether they will check or not. The excellent results obtained are sufficient reason for following the plan.

The method used at El Paso is described by H. F. Easter, as follows: Whether drossed at the blast furnace or at the remelting furnace, the bullion is sampled in the same manner, as follows: The bullion is tapped into a cast-iron cooling pot. The dross is skimmed off carefully and thoroughly. Before the final skimming the contents of the kettle are well stirred with the skimmer and the dross thereby raised is taken off completely. After skimming, the contents of the cooler are stirred again and, while the lead is still in motion, "gum-drop" samples are dipped. A few more gum-drops are taken than it is expected to make bars of lead, to insure having a gum-drop for each bar of lead. The bullion is ladled into molds, and after the pot is empty all extra gum-drops over the number of bars produced are thrown out. These gum-drops are held and delivered to the assay office whenever the bullion corresponding to them is removed.

A shipping lot consists of 780 bars (about 42 tons), and, when complete, the 780 gum-drops corresponding are placed in a graphite crucible and melted at as low a temperature as will give a homogeneous mass from which to dip the final gum-drop samples, upon which the actual assay of the lot is made. Great care is taken not to get the sample hot enough to oxidize the lead during the process.

The gum-drops, which weigh about 40 g. each, are assayed without clipping and the gold and silver calculated to an assay-ton basis.

A New Die Casting Metal

A new alloy which has recently been placed on the market under the name of "Ampco bronze" is unlike any other bronze in that it contains neither zinc, tin, lead or phosphorus. This new bronze was developed to supply the demand for a strong die-casting metal to be used in places where white metal die-castings were too weak and porous. Great difficulties have attended the attempts to form suitable die-casting copper-base alloys, as usually they melted at too high a temperature and attacked the dies when containing zinc and tin.

Ampco bronze is the result of ten years of research work, and is a 90 per cent copper-base alloy. It can be die-cast in permanent steel molds to finished dimensions and has great strength at high temperatures. This enables this metal to overcome the strains set up in the castings in the die molds while the metal is cooling and shrinking in the die.

This bronze is produced in several grades, differing slightly in composition, but considerably in physical properties. They have a range of tensile strengths of from 50,000 lb. per square inch to 100,000 lb. per square inch; elastic limit of 25,000 lb. per square inch to 45,000 lb. per square inch; elongation of 50 to 6 per cent; hardness of 70 to 280.

The metal is non-corrodible by acids, malleable, ductile, and can be forged, hammered, rolled or drawn. The tests given above are for sand castings. The forged, rolled and drawn metal has a tensile strength up to 150,000 lb. per square inch.

It is manufactured by the American Metal Products Company, Milwaukee, Wis.

Personal

Mr. **W. R. Cox** has been appointed professor of mining and metallurgy in the Oregon School of Mines, vice G. Montague Butler, resigned.

Mr. **A. C. Dart** has returned to Denver after an absence of several years and has again entered the professional field as a mining and metallurgical engineer.

Mr. **John Gross** has returned to Denver from Central America and opened his office as metallurgical engineer at 523 McPhee Building.

Mr. **P. Kranefeld** has removed from Montreal, Canada, where he was representing the Krupp concern, to Denver, Col., and will continue to specialize in crushing and grinding apparatus.

Mr. **Phillip J. Krell** will become manager of the new plant of the International Oxygen Company in the course of erection at Verona, Pa.

Mr. **J. P. Mooney**, formerly with the B. F. Goodrich Co., Akron, Ohio, has been appointed sales manager of the commercial department of the Hyatt Roller Bearing Co., Newark, N. J.

Mr. **James J. Ormsbee**, recently with the Tacoma and Hayden Smelters of the A. S. & R. Co., is spending a short time in New York.

Mr. **W. Acheson Smith**, general manager of the International Acheson Graphite Co., was elected on Nov. 2 one of the commissioners of the new commission government of Niagara Falls.

Dr. **Walter O. Snelling** of Pittsburgh, Pa., will erect an extensive laboratory in Long Island City, N. Y.

Dr. **Charles P. Steinmetz** was elected president of the common council of Schenectady, N. Y., on the socialistic ticket, on Nov. 2.

Mr. **W. R. Thurston** has been appointed manager of the Mine & Smelter Supply Co.'s Salt Lake City branch.

Mr. **Howard H. Utley** is local manager for the River Smelting & Refining Co., a new concern which is remodeling the old pyritic smelting plant at Florence, Col., to suit the requirements of proposed operations. **L. V. Emanuel** is superintendent and **George B. Clark** chemist.

Mr. **H. P. Zeller** has resigned his position as assistant superintendent of the coke plant of the Republic Iron Steel Company and has become superintendent of the new by-product plant of the Toledo Products Company.

Obituary

Abraham Van Winkle, president of the Hanson & Van Winkle Company, Newark, N. J., died on Sept. 30. He had been active in the electroplating trade for over forty years, and his untiring energy had made him a commanding figure. Born in Pompton, N. J., he was first interested in the drug business in Newark, N. J., but in 1870 went into the plating field. He was interested with Dr. Edward Weston in the first low-voltage dynamo made in this country. This dynamo was exhibited in Philadelphia in 1876. Mr. Van Winkle was also connected at one time with the Brush Electric Company, and his successes were instrumental in the forming of the U. S. Electric Lighting Company. He manifested at all times a great interest in all the affairs of the electroplating trade as well as in electrochemistry in general. His loss is keenly felt by all who knew him.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(*Continued*)

225,571, March 16, 1880, Patrick Concannon of Wallingford, Conn.

Relates to a rack for holding spoons and the like which are subjected to unequal wear, the spoons being held at the points of least wear. The holding clamp is mounted on a small shaft provided with a pinion which engages a movable toothed rack to oscillate the pinion, thereby dipping first the bottom of the bowl of the spoon in the electrolyte, then the underside of the handle, these portions receiving the greater amount of wearing use. Several spoon-holders are arranged in one frame to operate simultaneously. The device may be used for replating worn spoons.

234,775, Nov. 23, 1880, Robert B. Herskell of Wallingford, Conn., assignor to Simpson, Hall, Miller & Co. of same place.

Relates to a holder to support spoons and the like to be electroplated, and which are subjected to unequal wear. On opposite sides of the plating tank are arranged two uprights which support a cross-bar between them, the height of the cross-bar being adjustable. Upon this bar are fastened brackets to hold the spoons, the latter may therefore be immersed in the plating solution to any desired depth. Upon the remaining sides of the tank are arranged shelves supporting contact plates, the spoons resting on the contact plates and

the edge of the tank and extending into the solution, the outside of the bowl of the spoon dipping slightly in the solution so as to receive a deposit over a limited area.

245,206, Aug. 2, 1881, Hans J. Müller, of New York, N. Y., assignor to himself and Alexander Levett of same place.

Relates to protecting plating baths from reversing the polarity of the field magnets of a plating machine, and refers to his prior patent, No. 241,053, dated May 3, 1881, for a dynamo, which should be consulted with this for an understanding of the invention, which consists broadly in providing an extra circuit, using a carbon cathode, through which enough current is flowing to keep the fields excited.

248,436, Oct. 18, 1881, Thomas A. Edison, of Menlo Park, N. J., assignor to the Edison Electric Light Company, of New York, N. Y.

Relates to cells for depositing copper or the like upon the joints between the carbon filament and leading-in wires of an incandescent lamp. The cell consists of a tubular shaped body having a flared opening at the bottom, to receive a rubber stopper. The stopper is perforated to receive the glass tube of the lamp-stem supporting the leading-in wires, the stem being adjustable in the perforation to bring the joint just below the surface of the electrolyte. Instead of a cell consisting of a single tube, it may be a larger vessel having a plurality of openings in its bottom to receive stoppers. In the plating operation, the leading-in wires are connected as cathode, a suitable anode or anodes being suspended in the electrolyte. The electrolyte is drawn off when the plating operation is completed.

258,214, May 23, 1882, Alexander Brinckmann, of Astoria, assignor to himself and George H. Wooster of New York, N. Y.

Relates to supporting frames for small articles like "plate-pins" used in piano-fortes, and the like, such articles being too small to be held in any of the usual clamps. The supporting frames consist of one or more sheets of metal, preferably a plurality, the sheets being secured in parallel planes by metal supports at the corners, the bottom sheet having a plurality of small irregularly shaped perforations too small for the pin to fall through and making contact at points; the upper sheets being perforated with registering holes larger than the pin, to allow circulation of the electrolyte around the pin. In use pins are inserted in the alined holes, and the frame immersed by wires or rods in the electrolyte, and connected as cathode.

297,669, April 29, 1884, Charles F. Brush of Cleveland, Ohio.

Relates to apparatus for electroplating carbons for arc lighting, etc., and refers to his prior patent No. 196,425, which relates to the advantages of electroplated carbons. The present apparatus consists of a plurality of individual depositing cells connected in series, each to receive one carbon connected as cathode, and having a tubular anode. A tube to supply compressed air is also inserted in each cell, the compressed air stirring the electrolyte. The inventor finds it necessary to connect the cells in series, using a high potential current to supply the current necessary for plating, on account of the irregularities in individual carbons, these irregularities causing uneven and irregular deposits when the carbons are connected in parallel as usual.

310,146, Dec. 30, 1884, Arthur Murphy of Taunton, Mass., assignor to himself and Charles Minchew.

Relates to baskets and the like made of glazed earthenware, etc., and having perforated sides and bottom. Attached to the bottom are a plurality of metallic buttons electrically connected to each other and to a metallic suspending hook attached to the bail or handle of the basket. The apparatus is for electroplating tacks and other small articles.

331,609, Dec. 1, 1885, Herman R. Boissier of New York, N. Y.

Relates to methods of connecting the electroplating tanks to a dynamo. With a series dynamo, a small quantity of work in the plating bath does not permit enough current to pass to supply the field magnets, consequently the plating operation is exceedingly slow. The inventor provides an extra tank connected across the brushes of the dynamo, the extra tank containing an anode and cathode, and may be used for quick work; when not thus used it serves to produce electrolyte by the solution of the anode. The field magnet coils are provided with several shunts which may be used to vary the current flowing through the fields when the principal plating tank is filled with work.

369,457, Sept. 6, 1887, Morris H. Levett of New York, N. Y., assignor of one-third to Louis Levett.

Relates to electroplating tanks, and is for a folding removable inner cell made of fabric supported by wire mesh sides and bottom. The fabric cell is so made that its sides may be folded inward and entirely cover the bottom. In use, a plating tank accumulates a lot of scum and sediment, which renders the solution turbid. This sediment settles on the fabric bottom; the fabric sides are then folded down to inclose it, the fabric cell then lifted from the tank and cleaned. The inner cell thus serves to maintain a clean electrolyte.

Book Reviews

The Analysis of Non-Ferrous Alloys. By **F. Ibbotson** and **L. Aitchison.** Octavo, 230 pages, 19 illus. Price, $2.25. London and New York: Longmans, Green & Company.

This is intended for laboratory instruction as well as for use by the works' chemist. It is admirably adapted for both purposes, being keenly analytical in its method of presentation, explaining clearly the *why* and *wherefore* and the scientific basis for the methods described. It is up to date, as seen by it describing the analysis of the new high-speed tool alloy "stellite." It is, however, limited to the determination of lead, copper, bismuth, antimony, tin, arsenic, aluminium, chromium, nickel, cobalt, manganese (iron) and zinc. The other non-ferrous metals and non-metals occurring in alloys (such as cerium, silicon, phosphorus, titanium, molybdenum, etc.) are not considered. Within the limits treated it is a most admirable book.

Principles of Physical Chemistry.—By **Edward W. Washburn.** Octavo, 445 pages, 61 illustrations. Price $3.50. New York: McGraw-Hill Book Company, Inc.

The sub-title states that the treatment is from the standpoint of modern atomistics and thermodynamics, and that it is intended for students intending to enter physics or chemistry as a profession. It is not a laboratory manual, but a thorough discussion based on first principles, most admirably planned and very skillfully executed. The mastery of the author over every phase and topic is in evidence throughout the book, giving to the reader a sense of confidence in the information and lending a charm to the reading which is as refreshing as it is unusual. The book pre-supposes a knowledge of general chemistry and physics, and in mathematics the elements of differential and integral calculus. Anyone with this equipment will find this book probably the best help he can get in print to a thorough acquaintance with and a working knowledge of the principles of physical chemistry.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIII NEW YORK, DECEMBER 15, 1915 No. 16

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH OF EACH MONTH BY THE

McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DeMOTT, Treasurer

239 West 39th St., New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Col.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1915, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for December 15, 1915

EDITORIALS:

Alumina in Steel 933
Lake Superior Iron Ore Prices 933
High-Grade Spelter, "Not Quite So Valuable as Diamonds" 934
How the Steel Market Is Made 934

READERS' VIEWS AND COMMENTS:

What Metallography Can Show. By Francis A. J. FitzGerald 936
"While You Learn from Mistakes, Make Your Mistakes on a Small Scale," By L. Heynemann 936
Efficiency of Preparedness in Business. By John Calder .. 936
University and Chemical Industry (Joint Meeting of New York Sections of American Chemical Society, American Electrochemical Society, and Society of Chemical Industry) 939
The Iron and Steel Market 941
The Naval Consulting Board of the United States. By Dr. L. H. Baekeland 943
The Cyanide Plant of the Baker Mines Co., Cornucopia, Oregon. By Robert M. Keeney 947
Metastability of Metals. By A. Vosmaer 953
Thermal Principles of the Blast Furnace. By J. E. Johnson, Jr. 954
Faraday Society Meeting 962
Extraction of Radium, Uranium and Vanadium from Carnotite 965
General Meeting of the German Bunsen Society for Applied Chemistry 965
The Character and Extent of Atmospheric Pollution in English and Scotch Towns. By John B. C. Kershaw 967
Recent Chemical and Metallurgical Patents 971
Synopsis of Recent Chemical and Metallurgical Literature 973
Ozone for Ventilation 975
Oil Drying and Purifying Outfits 977
Turbine Vacuum and Low-Pressure Boiler Feed Pump 978
Personal 978
Dinner to Director Van H. Manning of the Bureau of Mines .. 979
Obituary 980
Book Reviews 980

Alumina in Steel

The article by Mr. G. F. Comstock in our issue of December 1 has apparently a bearing on the problem of steel failures. It seems to be recognized that many failures are caused by the inclusion and segregation of non-metallic impurities. These have been clearly shown by metallographic examination and it has been a general custom to designate them as "slag" inclusions. By some it has been maintained that many so-called "slag" inclusions are really alumina derived from the oxidation of aluminium additions to the steel during the process of manufacture and that these alumina particles show a particularly objectionable tendency to segregate. This, however, could only be regarded as an hypothesis unless some trustworthy method for detecting and distinguishing these as alumina could be devised. Mr. Comstock's paper apparently shows that this can be done and paves the way for reasonable discussion.

The brief letter by Mr. F. A. J. FitzGerald, which we publish in the present issue with respect to Mr. Comstock's article, is refreshing in its frankness and a particularly interesting illustration of what metallographic examinations can reveal.

Lake Superior Iron Ore Prices

An annual event of no little importance in the iron trade occurred on Dec. 8, Lake Superior iron ore prices for the season of 1916 being announced by the merchant ore interests. The prices named represent, broadly speaking, an advance of 75 cents a ton from the schedule that obtained for the 1915 season, that schedule being practically identical with the schedules obtaining in 1912 and 1914, and the lowest since 1904. The 1916 prices are about 50 cents a ton under the schedule ruling in 1907 and 1910, the highest since 1900. The new prices are: Old range Bessemer, $4.45; old range non-Bessemer, $3.70; Mesaba Bessemer, $4.20; Mesaba non-Bessemer, $3.55, per gross ton, on Lake Erie docks.

Unlike contracts in many branches of the finished steel trade, iron ore contracts are rigidly adhered to. The tonnage sold must be taken. A unique feature of the trade is that instead of payment being made according to delivery the payments are in twelve equal monthly installments, May 1 to April 1, whereas the deliveries, being subject to lake navigation, are chiefly from May 1 to Dec. 1. An interesting feature of the ore contract is that the buyer is given a guaranty that the seller will not sell others at a lower price. Nominally, this is a protection merely given the buyer; practically, it is a safeguard the seller throws around himself.

Improved practice at blast furnaces in recent years in the use of the dusty ores of the Mesaba range is

shown in the decreased price differential between Mesaba and old range ores of non-Bessemer grade. The differential is now well established at 15 cents. From 1905 to 1911 the differential was 20 cents, while in 1902 and 1903 it had been 40 cents. In previous years the differential was apparently less, but in actual fact the dustier Mesaba ores then had no vogue at all. The present 15-cent differential comes about from the desire of the old range producers, not the Mesaba producers. It is not that the Mesaba producer desires to keep his price up, but that the old range producer desires to hold his down, as otherwise he would suffer in the competition by not finding a broad enough market for his product.

High-Grade Spelter "Not Quite So Valuable as Diamonds"

The war has affected all metals and chemicals to a greater or less degree, but one metal indeed erratically. That is the "unusual" metal zinc. The impelling cause lies in the vast amount of spelter used for cartridges both for artillery and small-arms in form of a brass of a mixture 70 per cent copper and 30 per cent zinc suitable for rolling into strips or "discs." The constituent metals of this alloy must have and give peculiar physical and chemical properties, or otherwise cracks, seams and splits occur in the "flowing" and drawing of the metal. Any lack of homogeneity or ductility causes defects. Oxides, sulphides or an excess of lead are specific malignant impurities, although care in casting, rolling and annealing will lessen their effect. A certain number of "rejects" will be made and the cost of manufacture increased. What grade of spelter to use depends largely on the difference in prices, although small-arms cartridges are practically all made from 99.90 per cent spelter. For such class of work as condenser tubes, etc., high-grade spelter is also needed.

For years the production of high-grade spelter has been in the hands of the New Jersey Zinc Co., one of the aristocrats of the metallurgical world, but the "spread" between high-grade and "Prime Western" spelter is so great that several new producers have entered the field for small lots of high-grade which has sold as high as 52 cents, while even now the market is from 30 to 35 cents. The electrolytic zinc works, chief of which are those at Trail and Anaconda, are making a zinc of high purity. The American Zinc Lead and Smelting Co. and the Grasselli Chemical Co. are both producers of spelter analyzing over 99.85 per cent zinc and cadmium. There are others producing a strictly intermediate or 99.75 per cent. The "American" standard "high-grade" calls for 99.90 per cent, Fe 0.03 per cent, Pb 0.07 per cent, Cd trace. Metal like this is produced by the American Smelting and Refining Co. at its Pueblo plant, and by the American Spelter Corporation with works at Kusa, Okla., the latter company being sponsored by Messrs. J. L. de Saulles and G. M. Heckscher.

Whether or not such metal, though made by a process once used at Bertha, will prove equal to Bertha or Horse Head is open for debate. We are inclined to think that though it is an excellent substitute it will not surpass it, especially for the finest galvanizing. We judge this to be due to what might be termed "geologic individuality." The elements often behave as though they varied with the locality. Arsenious oxide when dissolved in the solvent and precipitated as Paris green, will give under the same conditions products of different properties when from different mines. Fake copper, certain steels, also show evidence of "geologic individuality of the atom," although sometimes the difference comes from minute impurities. Of course, in the case of spelter rare elements like gallium and indium may account for the difference, but "we hae ours doots." However that may be, the pure race of high-grade zinc commands a premium. Saith the buyer to the zinc salesman, "You are trying to sell me something not quite so valuable as diamonds."

How the Steel Market Is Made

Not since 1899 have finished-steel prices displayed such a strongly advancing tendency. The movement of that year cannot be regarded as a precedent or as an illustration, extreme or otherwise, of a market movement in the steel trade, for the steel industry was just finding itself. The period of industrial depression which according to common standards embraced the five years 1893 to 1898 inclusive may be said to have begun earlier in the case of the iron industry, for the pig-iron output of 1890 was not equalled in immediately following years, and during 1890 there was a rapid and extensive fall in pig-iron prices with no substantial recovery in immediately following years. Assuming then that in the iron industry at large the depression began in 1890, the industry entered the depression with wrought iron the dominant product and emerged from it with mild steel as the dominant product. During the depression the change from wrought iron to steel was effected. Some manufacturers, the Carnegie interest being a prominent example, were able to finance the change from wrought iron to mild steel. Others were not. Their plants became effete and dropped out of the reckoning. When demand for the wrought product reached normal, or perhaps slighting supernormal, proportions, the capacity was not available and a veritable boom in prices resulted. General industrial and financial conditions such as obtained in 1899 might recur at any time, but the conditions then existing in the steel industry could not recur, for the steel industry was then for the first time finding its place.

There have been many movements in the steel market since 1899, major movements of which this is the fifth. It is interesting to analyze the conditions that have developed in these movements and attempt to trace the reactions that produced the conditions. In such a study one finds reactions that suggest the catalytic agents as often active in chemical reactions.

Demand and supply are elements in trade which produce reactions, not as chemical elements do through chemical affinity, but through one or the other preponderating. If demand exceeds supply, prices tend to rise. The physical conditions obtaining in the manufacture, distribution and use of steel products are such

that in most finished-steel products it is the jobber or manufacturing consumer who carries the stocks, not the producer. The course of the steel market from year to year has often been strongly suggestive of an underlying trade law, that the carrying of stocks by the producer tends to stabilize prices while the carrying of stocks by the buyer tends to promote fluctuations. One must distinguish between actual ultimate consumptive demand and market demand. The period of prosperity which began early in 1901 and quietly disappeared in 1903 was one of strong consumptive demand. The period extending from late in 1904 to late in 1907 was a similar one, but with the prosperity still more marked. In each case the increase in actual consumptive demand was so marked as to lead to the addition of much productive capacity.

The next two steel-market movements, centering in 1909 and 1912 respectively, were different in extent from their two predecessors, but they were different also in character, in that the demand which causes prices to advance, by being in excess of the offerings, was a market demand not based wholly upon an increased consumptive demand. In each case the inception of the movement found stocks of steel in the hands of jobbers and manufacturing consumers at an extremely low ebb, while later on at the point at which the shipments of mills began to decrease these stocks were much larger, the result of the demand having been partly a market demand and not wholly a consumptive demand. The market demand was created by the fact that prices advanced from time to time and buyers were allowed to place contracts for specification and shipment in future periods. Such contracts would prove profitable to buyers as long as prices should advance.

The extremely heavy consumptive demand in 1905, 1906 and a large part of 1907 prompted the addition of much new productive capacity, and the almost complete collapse in demand that occurred late in 1907 found the steel industry not only with a large capacity, but with much new construction work in progress. Realization of the condition gave the industry a chill from which it did not recover for years, if indeed it is fully recovered even now. New construction has been undertaken with relative timidity since 1907. The market movements of 1909 and 1912 did not produce great waves of new construction. To-day the steel industry finds itself with a smaller increase in capacity over that in existence in 1907 or definitely under construction, than has occurred in any corresponding period in the past.

Given a restoration, or even partial restoration of normal consumptive demand, in keeping with the growth of the country, and an adventitious demand for steel for war purposes abroad, to the extent of a very few million tons a year, the steel industry was at the beginning of this year ripe for another major market movement. The extreme tightness of money late in 1914, coupled with an industrial depression and a continued decline in steel prices, produced the condition that stocks of steel in the hands of jobbers and manufacturing consumers were, in proportion to the size of the steel industry, easily the smallest on record. Conditions were precisely ripe for a market movement, and one based not necessarily upon greatly increased consumptive demand, for the market demand would of itself do much toward carrying a movement along. The steel mills evidently recognized the fact that a market demand could be developed. In several products they followed the policy of naming one price for material if specified once, and another price a dollar a ton higher on a contract that would permit specifying in some later period. For several months the market carried itself along nicely, with this market demand as the chief foundation. Gradually the "war orders" were found to constitute an important tonnage, and actual consumption at home began to increase. Important freight-car orders were placed in May, after many months of practically no railroad buying.

To make a long story short, with increased exports, increased domestic consumption, and a strong market demand due to jobbers and manufacturing consumers being willing to contract ahead, and also if necessary store material in their warehouses, the steel mills eventually found themselves crowded with work.

In analyzing the present condition itself, and the conduct of the market in the past two months, one discovers evidences of catalytic influences already referred to. They do not directly increase or decrease the consumptive demand for steel, or the productive capacity by a single ton, but they affect profoundly the flux of the market. The first is the legal situation, and the mental attitude of sellers of steel, produced by the suit of the government against the United States Steel Corporation, settled in the United States District Court June 3, 1915. The suit developed the fact that sellers of steel should not agree upon market policies. Previously their minds had met at times in an effort to prevent prices from falling, and they had also met at other times to prevent the market's own advancing tendency from carrying prices to a level that might later prove unsafe. The circumstances of the steel suit indicated that such policies ought not to be followed in future and the mental attitude of the steel trade became that it would be just as well, or better, to allow prices to advance as much as they would.

The second catalytic action was the war, and the effects it has produced in trade generally. Spectacular advances have occurred in various commodities. Some of the non-ferrous metals, and many chemicals, are selling at multiples of their former prices. Men's minds are open. Unprecedented advances are regarded as distinct possibilities when everything is so upset. Buyers give countenance to price advances that would be looked askance under normal world conditions.

The catalytic influence of these two elements is beyond question very important in the reactions that are making the steel market. The developments to date are remarkable, and no one knows how much may still occur. From the lowest level since the fore part of 1899 steel prices have risen in a twelvemonth to the highest level since 1907, and yet the prices used for comparison are practically nominal, for the mills accept but a small part of the tonnage offered them.

Readers' Views and Comments

What Metallography Can Show

To the Editor of Metallurgical & Chemical Engineering:

SIR:—An incident in the course of the work reported by Mr. Comstock in his article on "Alumina in Steel" in your issue of Dec. 1 may be of interest as showing the trustworthiness of the conclusions drawn from his micrographic investigations.

The 10-lb. steel ingots used for confirmatory tests were made at the FitzGerald Laboratories by melting the special steel, mentioned by Mr. Comstock, in crucibles made from 6-in. Acheson graphite electrodes and lined with electrically sintered magnesia prepared by the Norton Company. The crucibles were heated in an electric furnace of the kind illustrated in *Electrochemical and Metallurgical Industry*, Vol. III, page 56, Fig. 6, and a new crucible used for every heat unless the melt poured so as to leave the crucible perfectly clean, free from any skull or slag sticking to the lining.

In preparing the ingots treated respectively with aluminium and titanium three heats were made. Of these the first and third were with additions of 0.2 per cent of aluminium, the second with 0.2 per cent titanium in the form of ferro-carbon titanium, but in marking the ingots the sample from the second heat was labeled "No. 3 Titanium," while that from the third was marked "No. 2 Aluminium."

Now in all the experiments the same crucible was used, for the metal poured so cleanly that in no case was an appreciable residue left in the crucible. However, a few days after the sample ingots had been sent to Mr. Comstock an inquiry was received as to whether Sample 2 had not been made *after* Sample 3 and the same crucible used in both cases, because in addition to the alumina found in Sample 2 a small quantity of titanium nitride was detected in the metal, and this was the only hypothesis to explain its presence.

FRANCIS A. J. FITZGERALD.

The FitzGerald Laboratories, Inc.,
Niagara Falls, New York.

"While You Learn from Mistakes, Make Your Mistakes on a Small Scale"

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In your issue of Nov. 15 I note an editorial entitled "Make Your Mistakes on a Small Scale." The following anecdote illustrating the wisdom of your editorial may interest your readers. It was told me by an old Jew, well versed in the Talmud and in Hebrew lore.

A certain nobleman in Hamburg, Germany, who had inherited title and wealth and had spent his time in the manner of the idle rich, determined quite late in life to speculate on the Hamburg Exchange. His ventures all went wrong. One morning on the floor of the Exchange, he accosted Mr. Moses, an old successful Jewish speculator. "Mr. Moses," he said, "Why is it that in the year I have been a member of this Exchange I have lost money on everything I have touched, and you seem to be making it? It does not seem to me that I am so much less intelligent than you are. Will you not tell me the secret of your success?"

"Oh, yes," said Mr. Moses, "I will be glad to tell you what I think is the reason. When I was a youngster of 13 years of age my father told me that he could not afford to send me to school any longer, and that I must make my own living. He sent me away from the little village where we lived with one dollar, and said, 'My boy, go out and see whether you cannot make a little money with this dollar.' I left the village and passed an old woman, leaning on the gate of a farm, and I asked her whether she did not have something to sell. She said that she had an old copper kettle for sale. Before purchasing it I went and inquired the price of copper from a junk man and returned to the old woman and asked her to weigh the copper kettle. She did so and I figured that I could make a little money according to the market price of copper and bought the kettle. When I came to sell it, the junk man, to my consternation, would not pay me the price I expected. His reason was a very good one; the copper kettle had a wooden handle, which I had not noticed. I returned to my father in tears, and he consoled me and gave me another dollar. I again went out and purchased a hide. When I came to sell the hide I could not get the price expected, because the hide had no tail, and those special hides without the tail did not command the full price, and again I returned to my father in tears. In this way I paid for my apprenticeship when I was very young *and in small amounts*. I buy no more copper kettles with wooden handles, nor hides without tails."

Thus spake Mr. Moses and walked away, leaving Mr. Nobleman to reflect on the aptness of the story.

L. HEYNEMANN.

San Francisco, Cal.

Efficiency of Preparedness in Business

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I was much interested to read the editorial in your issue of Nov. 15 on the process of inception in invention.

A month ago I spoke before the Efficiency Society in New York on the inception of business and engineering ideas in a lecture on "Efficiency of Preparedness in Business." This lecture, which follows, may be of interest to your readers.

The fact that a thing works proves that it is effective, but it may be far from efficient. The difficulty in measuring efficiency in preparedness increases steadily as we work back from performance and production to forecast and vision. I leave to others more competent the subject of economic laws governing all business ventures, and confine myself to inceptions not ruled out on this score.

Preparedness is a large topic, but to most business men it has a very limited significance. To some it means merely the enlargement of export business; to others a more or less organized readiness to take advantage of new opportunities at home; still others regard it as a call to greater efficiency in the tasks already in hand and in statistical analyses to that end. Some think of it as chiefly concerning campaigns of advertising, sales and distribution, and the anticipation of needs and styles, while others are wholly engrossed in producing commodities, and what they have not heard in the last few years about their shortcomings would hardly be worth listening to. The fact is that efficient preparedness is demanded nowadays at every stage in business, if we are to lead in the procession. It must be in evidence from the earliest thought regarding a promising idea or a generalization of value down to the elaborate formulation of specific plans to realize these ideas and to a host of precautions for launching them safely on the sea of experience and ensuring a successful voyage.

The efficient conducting of present business in its

many aspects is the matter upon which the Efficiency Society exercises most of its thought, but "preparedness" is essentially concerned with things more or less indefinite which are yet to arrive. I will, therefore, avoid covering the well-traveled road of "the art of getting things done," and dwell upon the qualities demanded for business "preparedness" in three relations, viz., *inception, organization* and *operation.*

I know of just three ways for attaining wisdom, and thereby efficiency and preparedness on anything, whether it be business or baseball, motors or morals. These are *thinking, imitation* and *experience.* Thinking is the finest way, imitation is the easiest way, and experience the most difficult way.

A preparedness attained solely by experience is apt to be laborious and long delayed. Reached by imitation alone it adds to our experience, but fails to develop self-reliance; whereas a wise provision attained by a well-disciplined mind concentrating on a problem is the best of all, for it is the earnest of more successes of the same kind.

Efficient preparedness in business is the result of the interplay of these three factors combined with the industry necessary to intensify them. Such preparedness, however, in the matter of inceptions cannot be always measured by the result of the project for many other elements enter into performance and enhance or nullify the original conception. It is for this reason that good ideas poorly supported are apt to be overlooked and that efficient support of a poor scheme is so often a thankless task. Proprietors are too little given to analyses of their failures, and bookkeeping rarely explains anything about poor inceptions.

INCEPTIONS

Consider first the nature of the mental processes that lead to the initiative and originality characteristic of preparedness. The thorough co-operation of the three wisdom factors I have named and the quality of the minds engaged are the sole factors conditioning the birth of new business ideas. Mental grasp and imaginative power exercised upon the real facts of the problem are paramount here.

Obviously if the inception of a policy or plan is insufficient, inaccurate, and, therefore, inefficient, it matters little what may be done later by good organization and operation to support it. The best thing that can happen to the many inefficient inceptions is that they should never see the light or that they should be submitted to the test of intelligent and fearless criticism.

Unforunately many of them reach the rank and file in business with executive indorsement, if not also with executive origination, and are *not* open to challenge. Thereby hang not a few sad tales about rainbow chasing. Actual business occurrences show that lack of thought, lack of imitation and observation, and lack of knowledge of scientific and industrial principles are to be found in men who have inceptions of the highest importance in their control. Good business is the art of selecting probabilities and poor business is the result of taking chances on possibilities merely.

Sound concepts, visions, forecasts of coming events or needs, or estimates of conditions by leaders in finance, commerce and industry are fundamentals in business preparedness, and in my experience those concerns have been most successful and stable where the fewest things, external or internal, "just happened." Lack of preparedness is always rooted in lack of provision or inaccurate estimates, and we do not know how many bad guesses at the future are made on the average by our professional forecasters or the men at the masthead of business. One authority says 10 per cent is the minimum, and that 30 per cent more just escape failure. It is quite certain, however, that in our modern civilization, with its international business relations, acquaintance with other people and their conditions, is not widespread, and planning, preparedness and clear thinking are none too prominent. The gambler's chance in this land of promise and of quick recoveries is all too common, but its days are numbered.

We need in both our home and foreign business outlooks more statesman-like qualities, for we are destined, if we accept the nomination, to lead the world's markets. We are at present the great creditor nation; whether we shall remain so depends upon a strict attention to preparedness not yet in evidence. It is very important, therefore, to start right with the elementary ideas of projects, and many of our business inceptions fail right here, though, unfortunately, the failure is sometimes concealed from the onlooker until capital has been irretrievably wasted upon the project, and then various more obvious but secondary reasons are advanced for the collapse.

There have been no more striking instances of this than in the adventures of some of our own men of finance in the realm of industry. Their failure and surprise at being unable to juggle with matter and men after the skillful fashion of the world of figures and speculation has been instructive. Again and again financiers of the keenest intelligence and success in their own special spheres have been fooled, not through the operation of the law of average but by inceptions and projects inherently uneconomical and needing no wizard to discover this. For any efficient preparedness in such cases we look in vain. Apparently they could not resist the attractive terms either offered or possibly conceded for their capital and they swallowed the bait whole, with the reservation that any resulting burdens could be fastened on the backs of others. The first element in efficient business preparedness is to start right, trusting to no adventitious aid from capital or influence to attain that for which we have not laid secure foundations.

In the matter of the inception of great business ideas the lack of the trained mind in the adult is almost beyond remedy. But even trained minds will fail here if they lack imagination. So far as my experience goes, nearly every good idea in business, embodied finally in a project, arose from trained minds carrying thought past all verified phenomena and experiences into the realm of intuition. In other words, the step attained by what is really the scientific use of the imagination was a step beyond the last solid ground. Imagination played with and around ideas and ultimately flamed into consciousness of that which was yet to be proved. All the great originators testify to this, and our ordinary minds operate in the same way. It was thus that Newton took the stupendous leap from a falling apple to a falling moon, and it is a true saying that "science only gives us *hints* of what by a higher method we come to know."

But with our imagination among the stars, our feet must be firmly planted on the ground, for we are not dreaming here; we are consciously cerebrating, and so long as we think correctly we must think of things as they *are.* The state of mind within us must correspond to the state of things without us whenever a call comes for comparing them. Some people are intellectually dishonest, and in inceptions decline to see what they do not want to see. It is as if a man relished cheating himself at solitaire. In all preparedness, therefore, a passion for facts should rule and we should be willing to go far afield to get all relevant experiences. The mind also should be a nimble one for immediate

decisions may be demanded. But given a clear, clean, intellectual start the originator of business and industrial ideas should launch out boldly in mental speculation; open-minded, struggling against preconceptions of ideas and of people; ready to correct imperfect estimates of things and of character, and to welcome any new truth when it has proved its title, despite its impact upon cherished beliefs.

Such thinking and brooding over facts, always fortified by personal experience, keen observation and resourcefulness, is the secret of power and of efficiency in business preparedness. It gives a man the ability to acquire, to marshall, to master ideas and to forge from them a weapon to conquer men, or commerce, or adverse circumstance. Such subjects as the search for new markets, the stimulation of old ones, new products, improved merchandise, reduction of the present huge cost of distribution and selling, the influence of tariffs, the present trend of these in our own and foreign countries, the demands of the export customer, his banking needs, not to speak of the purely internal problems of a business, these and a score of others should keep our inception departments working overtime at this momentous epoch in our commercial career when the shrewdest analysis is necessary to forecast the economic result to each business of the present waste of men and capital abroad.

I have devoted most time to inceptions, to the preparedness which sets to work, for fruitful ideas, the right quality of mind, with the appropriate experience, upon the external and internal problems of the near and distant future of a business. This is not arm-chair work by any means. It may and often does call for travel and contact with all sorts and conditions of men. A few of our great corporations with international connections are highly efficient in their preparedness, but the average American concern does little to develop preparedness for foreign opportunities. Fortunately, our Department of Commerce is steadily increasing its consular service in this particular and improving its methods of circulating information, but the benefits will not be reaped by our commerce until we go after this trade in earnest and take great preliminary pains.

ORGANIZATION

I will deal very briefly with preparedness in the later stages of business. What is the next stage in order of importance? System says one; capital says another; credits say others, and so forth. The second essential in my opinion is efficient *organization*. Here again the triple discipline of thinking, imitation, experience, must be brought to bear upon the issue. One of Kipling's characters explains the failure of a cherished project by saying, "Now I saw so clearly what things needed to be done that I forgot that things are only accomplished by means of *men*." He was a big man himself but he had failed to organize.

In these days organization is receiving much attention. It can never get too much, but I think a word of caution is needed. That organization is not necessarily best considered that is represented by the most imposing chart. It is quality not quantity that counts for most in the executive circle, and the wise selection of the brains of a business is all-important. Not only so, but the task is not done once for all. I do not mean by this that fussy interference every few months with a stabilized staff is desirable—that is simply evidence of incompetence higher up. But men change, or fail to develop; their characters deteriorate or we make a mistake in our early choice. Hence for preparedness we must revise from time to time our selections of the human factors in business, and always with the sincere desire to take the square man out of the round hole and put him where he fits.

Preparedness calls for truer discrimination of suitability than at present and, at the initial stages, more use of the science of character-reading and of the psychology and physiology of business aptitudes in which notable progress has been made in the past five years. The employment department is coming into its own. Under competent administration it is no longer a mere laborer's registry. It classifies aptitudes competently, and even the higher salaried men are no longer engaged upon chance impressions of their personalities.

OPERATION

I close with a few words on preparedness in the operating departments of business, which present the largest field. The new leaven which has been fermenting in business in the last ten years has worked chiefly in industry. Management has been struggling from an art toward a science, and, while I do not think it has attained that goal, the machinery of management, namely, system, has been evolving rapidly. Whether too rapidly or too completely we will not inquire here. The question before us is what is the essence of preparedness in the operating department; in its mills and plants and stores; in sales and distribution of products and in the office, clerical and recording functions of all of these?

The new element in preparedness is the use of the "scientific method" in attacking problems. The scientific method, however, is not any particular system nor is it a tool that you can keep handy on the shelf for occasional use only. It is as old as Socrates and the dawn of science, but in its conscious application to business it is as new as to-day. It is essentially an attitude of the mind which influences our business conduct, plans and decisions, and causes us habitually to observe, describe, analyze and classify with accuracy the phenomena which recur in our daily round.

The result is that we apply these analyses and experiences to regulate later affairs and shape all our records so that they are interpretive and constructive. At the same time all this is confined solely to the problems where it is *economically justified*. Many men of outstanding ability in inception do all of these analyses by mind and memory, but in the operating departments we need store houses for facts and conveyors for our decisions, and the real question of system economy is, What kind and how many? It is the possession of adequate discrimination in this matter that distinguishes the mere statistician from the efficiency business planner and forecaster.

Finally let me refer to the great importance of preparedness in labor management. Do not attend to all else and give the human problem "absent treatment." More and more society in this favored land is becoming just "all-of-us," and the capitalist or executive who does not want to belong is quite unfitted for the new industrial age. When times are tranquil and relations are harmonious, get acquainted with your people and let them become acquainted with you. Let trust and confidence be sown and you will not reap distrust and suspicion. Do not let the sowers of good-will be accompanied by a brass band or attempt to hasten the capitulation of the doubter by paternalistic policies which he cannot appreciate. Some one in all our large plants and organizations should be charged with this sort of preparedness; the sensing of the inarticulate but none the less real misconceptions—often grotesque—grievances and trivial grudges which, massed in time in narrow minds, are formidable obstacles to progress. Every business must meet the impact of troubles of outside

as well as inside origin but, if you know your people and they know you, you will not have to wake up in surprise and chagrin at the number of things you felt comfortably sure of, which turn out to be *not so*.

Here, then, is the conclusion of the whole matter of business preparedness. It is simply the concentration on the inceptions in every department of the best minds we have and the provision for systematically widening and recording experience. Behind every method, every practice, every custom in business and society alike lies an idea or group of ideas—a theory—a reason. Hence, the only practical things in life are ideas; the only *practical* man, the man of ideas, the man who *knows*, not merely the man who *does*. Behind our individual practice, whether we are conscious of it or not, lies the theory and only he who knows it possesses the rule of the higher practice and can take the next step wisely.

It is thus, on the last analysis, to the man of sound theory and of efficient mentality we must ever look for preparedness at its best, for better ways of doing the world's work, for progress and efficiency.

JOHN CALDER.

Lexington, Mass.

Perkin Medal Award to Dr. Baekeland

The Perkin Medal Committee, consisting of representatives of the different chemical societies of this country, has awarded the Perkin medal for 1916 to Dr. L. H. Baekeland.

According to established custom the presentation of the Perkin medal to Dr. Baekeland will be made at the January meeting of the Society of Chemical Industry in joint session with the American Chemical Society and the American Electrochemical Society.

The University and the Chemical Industry

Mass. Tech. Night at Meeting of New York Section of American Chemical Society

At the meeting of the New York Section of the American Chemical Society on Friday, Dec. 10, in joint session with the American Electrochemical Society and the Society of Chemical Industry, the symposium on "The Universities and the Chemical Industry" was continued. This was Mass. Tech. night, while for the preceding meeting (see our issue of Dec. 1, p. 885) Columbia University had provided the speakers, and in his introductory remarks the chairman, Dr. **T. B. Wagner,** stated that in a third meeting later in the season representatives of the chemical industry would have the floor.

President **Richard C. Maclaurin** of the Massachusetts Institute of Technology was the first speaker. The Massachusetts Institute is a university in everything but name. The industries of this country will never rise to what they ought to be until they become imbued with the spirit of the university, the scientific spirit. On the other hand, the universities will never rise to their true level until they become permeated with the spirit of industries. The growth of the chemical industries is reflected by the fact that at Mass. Tech. the study of chemistry has grown threefold in the last decade; to-day one-fifth of its total student body, or 350 students, take courses in chemistry or electrochemistry.

The function of the university is to help to organize industries on a scientific basis. Three essentials the university can give to the student: a knowledge of fundamentals in science, an appreciation of the methods of science and their application to industry, and the spirit of science, the spirit of research.

The real question is: Are the universities doing enough? They are limited by the available funds. The salaries of the professors should be raised—if only to one-tenth of what they might expect to earn in the practice of their professions. To attract better students to the study of chemistry the prevalent opinion that chemists are poorly paid must be overcome. The professors should be in closer contact with the industries; in this respect we should take a leaf out of Germany's book. The professor of pure chemistry must not be overlooked. The problem of America is to organize all available knowledge. A lot is stored up in the professors of pure chemistry, and even in textbooks. Perhaps our greatest problem is not so much to break new ground, but to make use of what we have. Germany became rich in peace by believing in the obvious, by having faith in the obvious. This America has still to learn, to believe in the organization of science for the industry. The universities want to help. They are imbued with the desire of rendering service, if only the industries will say what they want.

Dr. **Henry P. Talbot,** professor of inorganic chemistry at Mass. Tech. was the next speaker. The Carnegie Foundations for the Advancement of Teaching has recently undertaken an exhaustive study of the present status of engineering education, and Prof. C. R. Mann has sent out many letters of inquiry to many members of engineering societies. From the replies received it appears that what is considered most vital for professional success, are such personal traits as character, personality, innate ability, perseverance, temperament, leadership, aims—for self or work. But these are exactly the factors over which the universities have the least influence. Then there are traits which are largely God-given but can be fostered by universities—integrity and honesty, tact, ability to co-operate, resourcefulness, power of expression, ability to understand and deal with men, and cultivation of engineering spirit. The university may and should catalyze the latent powers which Nature has bestowed (using due care to avoid negative catalysis, which is far more likely to occur in the educational than in the chemical field), but the university is practically unable to create such powers.

There still remains a serious criticism—that the graduates from our educational institutions fail to catch what may be termed the engineer's viewpoint, as applied to chemical industries. In the opinion of their employers they lack constructive imagination; they do not appreciate how diversified are the factors which enter into commercial operations nor the complexity of the human relationships and agencies involved; they have little business sense.

I can point out one particular in which it seems to me that our institutions are at fault: that they have not sufficiently required or even encouraged those of their staff who claim that they are fitting men for the industries to take adequate pains to acquaint themselves with the conditions under which those industries exist and prosper. It has been aptly said that the efficient teacher must have his knowledge in the "contagious form." It must be at least as true that the instructor who is capable of equipping his pupils to grapple with industrial problems in the broad sense, must have acquired the engineer's viewpoint, before he can impart it. I believe that we can only attain the best results when *every* instructor concerned with undergraduate courses has made such an acquisition, not merely *one or two* members of a staff whose particular business it happens to be to give courses labeled Industrial Chemistry or Chemical Engineering. The effect must be cumulative. . . . On the part of a teacher who has had some industrial experience, there is an increase of resourcefulness, especially in the matter of illustration of principles, which vitalizes his instruction. It surely need not commercialize his instruction; it does tend to enrich it and to give to the more academic phases of it, which must always be the backbone of the training, greater vitality. . . .

One of the most frequent criticisms of the young graduate relates to his inability to understand or make himself understood by other men; to his failures to co-operate with others or to direct the work of others, even though the latter are less intelligent than himself. It is quite possible that our schemes of instructions for the chemists and chemical engineers, as they have actually taken form, do tend toward more individualism, and less of concerted action than is true in the case of other engineering professions, where students are much more likely to work in squads. This matter deserves and is receiving some consideration.

Dr. Talbot thought it would be a great help if students could obtain even simple employment in manufacturing plants in summer. As to the instructors the universities should put a premium upon or, when practicable, demand of its instructing staff some sort of real contact with industrial processes. Even a round of visits among operating plants, of a fortnight's duration, is a wonderful education.

Undoubtedly the greatest service which the universities could render the industries in the training of young men would be to increase the proportion of large-minded, mature teachers. Unhappily, those entrusted with administrative duties realize that it is increasingly difficult (especially in chemistry to-day) to attract and hold such men (especially young men) in competition with the attractions in the technical field. This not alone because of the increased emolument which they offer; it is quite as much because of the opportunities for tangible achievement. It is, of course, too much to ask of the industries that they should refrain from securing the services of such men, but it seems very desirable to make an effort to devise some plan of co-operation which will, in a considerable number of cases, permit able men to serve the industries, without severing their connections with the educational institutions.

Dr. **William H. Walker,** professor of chemical engineering at Mass. Tech., followed. The university is not in that active co-operation with the industrial life of the country which makes for the greatest national efficiency and prosperity. In which respects have the industries failed to take their full part in meeting this demand for more efficient co-operation? The first criticism of the industries is their failure to make known to the university what their troubles and their problems are. This proposition is simple in its statement, but fundamental in its importance and far-reaching in its results.

One reason for this condition of things is that the industries have too little faith in the university as a source of help. A manufacturer consults the professional man and soon discovers that he does not know the details of his plant or his process or his product. He at once concludes that however able and learned the professor may be, he is too ignorant of the subject in hand to be of service. Here is where the manufacturer goes wrong. It is not only unnecessary, but as a rule undesirable, that the university professor should know the detail of the problem which is so familiar to the manufacturer. Co-operation signifies the combined striving of two people toward the same end. When the manufacturer contributes the practical details of the problem, and to this the university man adds a broad knowledge of the facts and principles of science, with a training and experience in the application of these facts and principles, there is created a team which will produce results to satisfy the most exacting. This is what co-operation means; and it is this combination of science and industry that has made Germany the power she is to-day.

A second reason is, that there is a lack of frankness and a want of confidence on the part of the industries when dealing with the University man, which so far as I know is not merited by him, and which too often makes efficient co-operation impossible. The university man . . . can aid efficiently and intelligently only when he is in possession of all the facts. If the scientist is not worthy of being intrusted with the whole story, he is a dangerous man to be in possession of any part of it. Nothing is more discouraging to the university man than to expend a lot of time and energy on a problem only to later find that he was kept in ignorance of conditions which made the results of his earlier work useless. If the scientific man cannot be a confidential man, his usefulness to the manufacturer has vanished.

The next matter in which the industries are at fault, is in not assuming a more liberal attitude toward the publication of the results of research work done for the industries by the universities and their graduates. There is a feeling on the part of the president or manager of the company that if the university man be generously reimbursed for his time and trouble that he should be satisfied. No scientific man should be, and few scientific men are, satisfied with a purely monetary return for their labor. They appreciate that they are under an obligation to contribute their share toward the development of their science. . . . In every piece of research work there are results which could be published in a perfectly impersonal way, so to speak, that would enrich science, and do the industries no harm. . . .

The unfortunate use of the words "pure" and "applied" research has led to the almost unconscious assumption that the only motive behind pure research is to enrich science, while the sole motive actuating applied research is to enrich the investigator or the organization financing the investigation. This latter assumption is unwarranted. Because an investigation is to be utilized, is no reason why the work should not be done with that thoroughness and accuracy which produces the best of scientific results. . . . Consider the splendid research carried on by Whitney and Langmuir on the behavior of gases at very high temperatures. It is immaterial whether you consider this the finest type of pure research from which the commercially valuable gas-filled tungsten lamp resulted, or an exceedingly profitable piece of industrial research in which purely scientific results of great value and interest were obtained, and given to the world. The goal toward which we should strive is to conduct our investigations so that the only distinction which can be drawn between pure and applied research, is the interval which will probably elapse between the time when the results are obtained, and the time when they become of service to the community.

A fundamental difficulty which presents itself when we in America attempt to introduce science into industry as compared to the ease with which the same thing is done in Germany, is occasioned by the absence of the equivalent of the equivalent of the German "technical director." . . . The average directing head of an American organization may have all the training necessary to be the son of the owner, or the representative of the majority stockholders, or of the banking syndicate which financed the industry; but he lacks the training which enables him to appreciate the atmosphere which must surround research work or in fact scientific work of any kind if it is to be successful. The infinite patience of the German investigator is made possible and profitable only by a corresponding infinite appreciation and sympathy on the part of the managing director. We may talk until the crack of doom about the miraculous results of Germany; but so long as we continue to draw the technical directors of our industries, the men on whom decision as to development work depends, from the purely commercial side of the organization rather than from those men with a scientific training, just so long shall we continue, notwithstanding our great natural resources, to cry for a protective tariff, more favorable patent laws, and other wholly temporary and superficial aids.

Finally we come to that factor in which the industries are most woefully lacking, and to remedy which the university has done almost nothing, namely the absence of intelligent foremen. . . . While science forced into an organization from on top is most helpful, some science introduced at the bottom is also necessary. . . . Here is a golden opportunity for the university, using this term always in the broad sense already stated, and the industries, to co-operate as they have never done before. All through the long summer the industrial and chemical engineering laboratories of our large institutions are empty. Why should this expensive equipment be idle when there are so many anxious to use it? Time does not suffice to outline in detail a plan which we are developing at the Institute of Technology, to present to young foremen and superintendents the principles of physics and chemistry on which their chosen industry depends. We propose to assemble each summer in our chemical engineering laboratory apparatus designed to present one specific industry. We shall invite that industry to send to us their more promising and ambitious men, in order that they may learn the scientific principles upon which the control of the raw materials, the process and the product depend. There are grave difficulties in such a plan, I admit, but co-operation can solve them. The objection met most frequently is that the industries cannot spare a good foreman for so long a time as six weeks. I can only say, that the foreman does not exist who may not at any time be taken out of the factory for six weeks by pneumonia, or typhoid fever, and yet the factory would not stop, nor the foreman loose his position. No more promising field exists, nor one fraught with greater possibilities for the industrial progress of this country than the opportunity which this

problem presents for co-operation between the university and industry. The foremen are anxious to learn; the industries are anxious to have them know; the universities are anxious to teach: Let's get together.

Mr. Arthur D. Little, in closest touch with the industry as president of Arthur D. Little, Inc., and in equally close touch with the Mass. Tech. as a member of its Corporation, made the final speech of the symposium. He pointed out that the part which science plays in furthering industrial development is not sufficiently appreciated by bankers, capitalists, men of affairs, and directors of industry, nor by superintendents, foremen, work people and the public generally. The directors of industry frequently ignore science. The attitude of superintendents and foremen and industrial workers generally to the innovation and betterments proposed by science is far too commonly one of militant scepticism or hostile suspicion.

Now all these individuals are social units who, with many other interdependent and mutually reacting units, together constitute the public at large. One may therefore fairly claim that our universities, great technical schools and colleges cannot serve business better than by directing some considerable part of their immense collective resources and influence toward creating in the public mind the mental atmosphere in which only business can truly flourish.

The first great necessity of business, as it seems to me, is a wiser, less recklessly extravagant and more generally efficient government of nation, State and municipality, and, as a corollary, a higher respect for law in the community. The second urgent need of business is that of establishing in the public mind as axioms the broad facts and principles without such general acceptance of which business cannot be carried on at high efficiency anywhere.

Business for example suffers much from the notion prevalent in certain quarters that all wealth is produced by labor and none by brains. It is likely to suffer still more from the idea that the productive capacity of all should be limited by that of the least capable. So, again, is business hampered by the general ignorance of workers and superintendents as to what research is and what it can do for them. . . .

The University of Wisconsin has done much to raise the standard of government in Wisconsin. Other universities everywhere are doing something, but could do much more, to combat the influence of pernicious ideas and enlighten obstructive ignorance.

To those of us who come in contact in considerable numbers with recent university graduates, one of the most shocking defects in the educational system of which they are the product is found in the pitiful lack of decision exhibited by the majority of these young men concerning the work and place in the world for which they are best fitted. One gains the impression that all too often the educational processes to which they have been subjected have been akin to the Strassburg process of stuffing by which geese are fattened. Or, they have been taught as Dr. Johnson said books were made, as an apothecary puts up a prescription, by pouring a little from many large bottles into one small bottle. It is not surprising that both the Strassburg process and that of the apothecary should have failed to draw out and develop the native capacities and latent possibilities of the student or that they should leave him with no well defined directive impulse.

Such a state of affairs is happily not true of our technical schools and it ought not to be true of our universities. . . .

Those of us who have received the benefit of any sort of scientific training are constantly amazed at the ignorance of cultivated men and women, business men and work people, regarding the simplest phenomena by which they are surrounded. To a deplorably large proportion of the community the striking of a match, the lighting of a fire, the freezing of water, the fall of snow, the sending of a telegram or a talk by telephone, the operation of a steam engine, or the turning on of an electric light, involve mysteries as far beyond their range of thought as the cause of gravitation or the rotation of the nebulae.

Since business involves at every point contact with natural phenomena and since the proper understanding of these phenomena, or at least some realization of what underlies them, often determines the measure of success attained in business, the university might well establish a compulsory elementary course in general science. This should be designed to give the student at least a rudimentary knowledge of the field covered by the different sciences, the relation of their subject matter to natural phenomena in the affairs of everyday life and those of business, the interdependence of the sciences, and, above all, a clear idea of the scientific method. Such a course could not fail to prove an immense stimulus to any intelligent mind. It would open out new horizons for thought and put an altogether different and more interesting aspect on the world in which we live and in which we must do business.

The business man seldom has at his disposal any more potentially efficient tool than the English language, but in his hands it is a tool which is often rusty and very seldom so keen and highly tempered as to be capable of rendering its highest service. The fault for this is largely with our universities, and the remedy, so far at least as their own students are concerned, is in their hands. Our great institutions of learning are every day disgraced by the inability of their recent graduates to make a concise and convincing oral statement of a series of facts, to prepare a well organized and adequate report, or even to write a graceful and informing letter.

There is finally a very definite field in which our smaller colleges can do much for business, and that is by offering specialized courses in the science and technology of particular industries which are highly developed in their locality. Ohio State University, for example, has for years specialized in this way regarding coal, and the University of Maine is now instituting courses in paper making. Other colleges and universities are favorably situated as to particular industries, in such numbers and with such variety of opportunity that, were these opportunities utilized in even moderate measure, the young man who desired to prepare himself for any line of industrial activity would have within his reach the means of realizing his ambition.

The result would be the constant accession to the ranks of business of annual quotas of young men not blindly groping into an unknown world like the modern graduate, but advancing eagerly with open eyes toward responsibilities which they know that they can meet.

This closed the symposium on "university and industry." Dr. L. H. Baekeland then presented his address on the Naval Consulting Board which is printed in full on page 943 of this issue. Dr. W. R. Whitney, also a member of the Naval Consulting Board, added a few humorous remarks, and the meeting adjourned.

The Iron and Steel Market

Prices on Lake Superior iron ore for the coming season were announced Nov. 8 by the Cleveland ore interests. The schedule will probably be as follows: Old range Bessemer, $4.45; old range non-Bessemer, $3.70; Mesabi Bessemer, $4.20; Mesabi non-Bessemer, $3.55, per gross ton on Lake Erie dock. The standard or base ore contains 55 per cent iron in the case of Bessemer and 51.50 per cent iron in the case of non-Bessemer, natural state. For ores whose iron content is near that of the base settlement is made on a straight unit basis, in proportion to the actual iron content, but in case of considerable departure the system of computation is more complicated. In Bessemer there are phosphorus premiums and penalties, in accordance with departures from a base of 0.045 per cent phosphorus content. Generally speaking, the 1916 schedule is about 75 cents a ton above the prices of 1912, 1914 and 1915, the lowest since 1904, and 50 cents under the prices of 1907 and 1910, the highest since 1900. The entire advance of 75 cents for 1916 does not go to the ore producer, as vessel rates were recently established at 10 cents advance over the rate for 1915, and further advances are likely. The Steel Corporation set the 10-cent advance recently by chartering vessels to the extent of a 10,000,000-ton movement, and since then owners of vessels have been chary about contracting at all.

Shipments of ore down the lakes in the season just closed total 46,318,804 tons, against 32,021,900 tons in 1914 and 49,070,478 tons in 1913, the banner year. Besides the lake shipments about 750,000 tons of ore is usually moved by all-rail routes. The forecast is that 60,000,000 tons or more will be required next year, but doubt is expressed whether as much ore can be carried

by the vessels. There would be no difficulty about mining the tonnage, in all probability.

The steel market has come almost to a standstill as to the booking of strictly new orders, for a heavy tonnage continues to pour into the mills in the form of specifications on existing contracts. The mills will accept specific orders, at a price, for almost any delivery they can make, when it appears that the steel will be needed for a definite purpose, but the deliveries are such that buyers are but little interested. What many buyers would like to secure is protection for third quarter and later deliveries by open contracts, subject to later specification, but the mills are indisposed to commit themselves so far ahead.

The steel market is likely to be quiet, generally speaking, for two or three months while the mills straighten out their obligations. So heavy has been the specifying, and so rapidly have obligations piled up on mill books, that a great many arrangements have to be made with buyers. Often it occurs that a buyer will request that an earlier delivery be made on a specification filed later than another.

Emphasis should be laid upon the fact that the war demand is now a relatively minor factor in steel trade activity, domestic demand having increased so sharply in recent months. An illuminating comparison can be made. The last period of full activity in the steel industry extended from early in 1912 until late in 1913. The outputs in the calendar year 1913 may be taken as representing about 90 per cent as great a tonnage as would have been produced if the activity of the first nine months had been continued throughout the year. Dividing the outputs reported for 1913 by this factor we have: Pig iron, 34,500,000 tons; steel ingots, 33,600,000 tons; steel castings, 1,100,000 tons; finished rolled steel, 25,500,000 tons; finished rolled iron, 1,850,000 tons. Exports of steel products in 1913 amounted to about 2,300,000 tons. At the present time production is at the following estimated rates: Pig iron, 38,000,000 tons; steel ingots, 38,000,000 tons; steel castings, 1,000,000 tons; finished rolled steel, 28,000,000 tons, finished rolled iron, 1,500,000 tons. Direct and indirect exports probably represent about 7,000,000 tons of rolled steel, and more likely less than more than this quantity. Thus during the active portion of 1913 finished steel appears to have been delivered to the domestic trade at the rate of about 23,200,000 tons, while at present the rate seems to be about 21,000,000 tons, perhaps somewhat more. In most directions the domestic demand is much heavier than in 1913, for in 1913 there was more than 3,000,000 tons of rails produced for use in the United States, while the present production of rails is extremely light. There was also much more structural material consumed than is being consumed at present. Deducting for these two items, the domestic demand remaining appears to exceed quite materially that of 1913, the heaviest domestic demand that had been experienced up to this movement. The alignment is one that has been established but recently, and it is one that is perhaps not universally recognized even now.

Pig Iron

Pig iron has been advancing fully as rapidly since Dec. 1 as it did during November, the rate then, averaging various grades in the different markets, being between 35 and 40 cents per ton per week. The pig iron market has shown a very interesting reversal in its conduct as to prices. During the first six months of the year prices did not advance, although demand continually increased. Idle furnaces blew in from time to time and forestalled advances. In July, August and September demand increased further and moderate price advances occurred. In the past thirty days there has been little increase in the rate of consumption, and the tonnage demand in the market has been relatively light, yet prices have advanced very sharply, and evidently because the limit of productive capacity has been reached or closely approached. It is not demand alone, but the relation between demand and supply, that makes prices. The most spectacular performance has been by Bessemer pig iron in the valleys, which was quoted at $17.50 to $18, valley, in our last report, in the closing days of November. Early this month sales of 3500 tons were reported at $18, fixing the market at that as minimum, but within a few days sales of 1100 tons were made at $18.50, followed by sales of about 1500 tons at $19. There may have been other sales, but if so the trade at large did not hear of them. Never before had Bessemer thus advanced on such an extremely light turnover. We quote: No. 2 foundry iron, delivered Philadelphia, $18.25 to $18.75; f.o.b. furnace, Buffalo, $17.50 to $18; delivered Cleveland, $18.30; f.o.b. furnace, Chicago, $18 to $18.25; f.o.b. Birmingham, $14 to $14.50; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $19 to $20; basic, $17.50 to $18; No. 2 foundry and malleable, $18 to $18.50, and gray forge, $17.50 to $18.

Steel

There is no regular open market for billets and sheet bars. The mills are very short of steel and prefer to take care of their regular finished steel trade together with their regular billet and sheet bar customers, leaving nothing to be offered in the open market for such deliveries as the mills would care to consider. Based partly upon private settlements in the trade the market is regarded as nominally quotable at about $30 for Bessemer billets and sheet bars and about $31 for open-hearth, f.o.b. maker's mill, Pittsburgh or Youngstown. Forging billets are quoted at about $52, with a small turnover, and rods at about $40.

Finished Steel

Prices of some of the steel products have become largely nominal. In bars, plates and shapes the large mills have a minimum of 1.70 cents, which they seem about to advance to 1.80 cents, for shipment at mill convenience, no early delivery being possible, while the smaller mills, able to make earlier deliveries, are securing premiums.

Prices quoted are f.o.b. Pittsburgh unless otherwise noted:

Rails, standard sections, 1.25 cents for Bessemer, 1.34 cents for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.70 cents to 2.10 cents, base.

Shapes, 1.70 cents to 1.80 cents.

Steel bars and bands, 1.70 cents to 1.90 cents base; steel hoops, 1.90 cents, base.

Iron bars, 1.859 cents to 1.959 cents, Philadelphia; 1.60 cents to 1.70 cents, Chicago; 1.85 cents to 1.90 cents, Pittsburgh.

Plain wire, 1.85 cents, base; wire nails, $2 per keg, base; galvanized wire, 2.55 cents; painted barb wire, 2.15 cents; galvanized barb wire, 2.85 cents.

Sheets, blue annealed, 10 gage, 2.25 cents; black, 28 gage, 2.50 cents to 2.70 cents; galvanized, 28 gage, 4.75 cents to 5.00 cents; painted corrugated, 28 gage, 2.70 cents to 2.90 cents; galvanized corrugated, 28 gage, 4.80 cents to 5.05 cents.

Tin plate, $3.60 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 78 per cent off list; galvanized, 73½ per cent off list.

Boiler tubes (less than carloads), 68 per cent off list.

Structural rivets, 2.50 cents; boiler rivets, 2.60 cents.

The Naval Consulting Board of the United States*

BY DR. L. H. BAEKELAND
Member of the Board

Modern war, whether it be for robbing, plundering and subjugating other nations, or for legitimate self-defense, has become primarily dependent upon exact knowledge, good scientific engineering, and to a large extent, applied chemistry.

Napoleon used to say that the Lord was on the side of the armies with the biggest artillery and the best ammunition; if this seemed true in his time, it sounds almost like an axiom to-day, when physical training, personal valor, bravery, or courage, appear to count for little if efficient technical equipment, based on sound scientific knowledge, is lacking.

Germany, with her enormous and well-drilled army, with her 42-centimeter guns, and other formidable equipment, would be hopelessly paralyzed did she not find in modern chemical processes of synthetic nitric acid from the air, the source of supply of this indispensable chemical. How otherwise, could she manufacture smokeless powder and explosives, since England succeeded in shutting her off from the general source of supply of nitrates from Chili?

THE NAVAL CONSULTING BOARD

Secretary Daniels seemed to be imbued with these facts, when by organizing the Naval Consulting Board of the United States, he desired to give to our Navy the benefit of the scientific and technical talent of this country.

Since then his example has been followed by the French Republic, who in her hour of danger, has organized a similar civilian board and has even raised it to the dignity of a ministry: "Le Ministère des Inventions."

Great Britain also has enlisted the services of a board of civilian scientists and technologists for her present war operations.

As to Germany, we know that long ago she has abundantly availed herself in her war plans of the advice and co-operation of her scientists, inventors and engineers.

Although general information about the Naval Consulting Board has been more or less available through the daily press, there seems to be a very hazy conception in the mind of the public as to its work and plans. Unfortunately, some published criticisms, emanating mostly from persons who neither seem to have the desire nor the tact to first obtain correct information, have caused a very misleading interpretation of the work of this board.

A BOARD WITHOUT "POLITICS"

To those whose limits of imagination do not go beyond petty political considerations, it may be well to point out that in the formation of this board, politics has not had even the most remote influence. Secretary Daniels appointed America's best known inventor, Edison, as chairman, and by the latter's advice, applied afterward to different engineering and scientific societies of the United States, so that each of them should designate two representatives best qualified to serve on the board, through which our Secretary of the Navy would try, as he expressed it, "to mobilize the inventors and engineering talent of the country in the service of the United States."

Until now, Mr. Daniels does not know whether there are any democrats, republicans or progressives on this board—nor does he care to know. He relieved himself of the responsibility of selecting the members of this board by putting the matter up to the representative engineering societies of the United States. If any of those societies did not make the best possible selection, they alone should bear the blame. In the meantime, it matters little as long as the majority of the board are men of such ability and personality that they cannot fail to impress their attitude and talent upon the work of the board.

IS THE BOARD TOO CUMBERSOME?

At first it seemed as if a board of twenty-two men was to be much hampered by cumbersomeness and by long deliberations; but this fear vanished after our first meetings. If any member felt inclined to use unnecessary oratory or rhetoric, he soon changed his mind after he noticed how the other members displayed mutual respect for each other's valuable time, how discussions of secondary importance were eliminated, and how this board proceeded with unusual directness toward matters of immediate importance.

THE TRIP ON THE MAYFLOWER

When the announcement was made that on the first day of our meetings we were to board the yacht of the President to proceed to the Indian Head Proving Ground, some of us were inclined to think that formalities and social affairs might interfere with the efficient distribution of our time. But this idea also was soon dispelled, as during this entire trip, the time was taken up with the discussion of subjects directly related to our work, while becoming acquainted with the other members of the Naval Consulting Board, as well as with the chiefs of the different departments of the Navy.

So little time was given to formalities that even a regular lunch was dispensed with, beyond the distribution of a few sandwiches, while discussing various matters. Our visit to Indian Head gave us an excellent opportunity to get some direct practical information upon matters of ordnance and ammunition.

We landed back in Washington after dark, but at half-past eight that same evening, we were to continue our meeting at Secretary Daniels' office. Although this left us scarcely a few minutes to swallow some supper, none of the members of the board failed to appear at the appointed time.

A JOINT MEETING WITH THE CHIEFS OF THE NAVY

It is not generally known that the Navy had, in itself, an advisory board which is made up as follows: Hon. Franklin D. Roosevelt, Assistant Secretary of the Navy; Rear-Admiral W. S. Benson, Chief of Naval Operations; Rear-Admiral Victor Blue, Chief of Bureau of Navigation; Rear-Admiral Joseph Strauss, Chief of Bureau of Ordnance; Rear-Admiral R. S. Griffin, Chief of Bureau of Steam Engineering; Chief Constructor D. W. Taylor, Chief of Bureau of Construction and Repair; Civil Engineer H. R. Stanford, Chief of Bureau of Yards and Docks; Paymaster-General Samuel McGowan, Chief of Bureau of Supplies and Accounts; Surgeon-General W. C. Braisted, Chief of Bureau of Medicine and Surgery; Major-General George Barnett, Commandant of the Marine Corps, and Captain Ridley McLean, Judge-Advocate-General of the Navy.

All of us were impressed with the concise and business-like way in which each one of these gentlemen described his various responsibilities and presented the details of the subjects on which he desired the advice and assistance of the members of our board.

*An address made at the joint meeting of the New York Sections of American Chemical Society, American Electrochemical Society, and Society of Chemical Industry, Dec. 10, 1915.

Not only did they give us the convincing impression that they were sincerely glad to discuss their problems with us, but in doing so, they made us forget that they were the chief officers of the Navy; they appeared to us like so many engineering or business men who in a simple and direct way, wanted to discuss questions on which they felt their grave responsibilities. To anyone who is acquainted with all the pose and overbearing attitude of European military caste, and who might fear that this nation might bear the incubus of militarism, direct acquaintance with men like these would soon dispel this apprehension.

Nor did we see, anywhere among them, nor at the Army and Navy Club, nor at the Department of the Navy, as much as one single uniform, except, of course, on board the Mayflower, where the yacht's officers and crew were in uniform.

Notwithstanding the fact that no time was lost for unnecessary purposes, it was after midnight when the first day's meeting adjourned.

NO TIME GIVEN TO UNNECESSARY DISCUSSION

Early next morning we met again, this time at the library of the Navy, and then and there the board was organized for its future work. Here again, no time was spent upon side matters; everything was transacted in a practical direct way. For instance, when the rules of procedure for further meetings had to be discussed, a sub-committee was immediately organized with instructions to leave the room and report "not later than thirty minutes," so as not to impede other deliberations which were going on; the result was that when at noon we gathered for lunch, all questions of organization and subcommittees had been discussed, sifted and settled until future conditions may make it desirable to introduce any needed changes.

But even at lunch, the business meeting went on, and some of us had to interrupt our lunch, and go to a next room to deliberate further in a subcommittee, until a report could be submitted on some matters relating to this particular committee. So when at the end of this second day, the Naval Consulting Board adjourned, a good deal of work had been disposed of.

Shortly afterward another meeting was held in New York, where the organization of the subcommittees was completed, and where the different chairmen of the subcommittees were appointed.

A BOARD THAT RECEIVES NO PAY AND PROVIDES FOR ALL ITS OWN EXPENSES

For those who are accustomed to consider the United States Government as a big "milking cow" for salaries and remunerations, it may be of interest to know that no member of the Naval Consulting Board draws any salary, nor gets any remuneration from the Government.

We all pay our own traveling and hotel expenses and each member feels that if he can give his time, free of charge, to the Government, he can still better afford to pay his own expenses.

This program is carried out so scrupulously that even the cash for the purchase of stationery and printing is furnished by the members of the board, who are monthly assessed among themselves.

A "SHORT-CUT" BETWEEN THE NAVY AND THE INVENTORS OF THE COUNTRY

The general opinion of the members of the board is that its scope of usefulness can best be fulfilled by acting as a "go-between" or a "short-cut" to information between the heads of departments of the Navy, and any individual member of the different societies they represent. This carries into practice the idea of "mobilization of inventors and engineering talent" of Mr. Daniels.

The board mainly puts its services at the disposal of the chief officers of the Navy, as fast as the latter feel the necessity of co-operation or advice.

For instance, a subject relating to improvements in the manufacture or the composition of a certain explosive, would be referred to the subcommittee on chemistry and physics, as well as to the subcommittee on ordnance and explosives; the matter is discussed in these two committees and the members of these two committees decide whom to select among their fellow members of the chemical or engineering societies who are best qualified to help them in this task, and who, at the same time, are willing to co-operate without any other compensation than the feeling that they are working for the good and the security of our republic.

It is obvious that in handling all these matters, tact and discretion are just as indispensable qualifications as talent or knowledge, and this involves quite some responsibility for the members of the Consulting Board in selecting suitable collaborators.

As a matter of fact, several important pending problems are now actively before the subcommittees, and, notwithstanding the short time which has elapsed since the first meeting of the board, some of these questions are already in an encouraging phase toward successful solution.

THE SO-CALLED "FIVE-MILLION LABORATORY" OF THE NAVAL CONSULTING BOARD

The so-called "five-million laboratory," proposed by the Naval Consulting Board, has been the favorite subject of varied and picturesque criticisms which, as usual, originated more through lack of information than by ill-will.

Secretary Daniels requested each member to address to him his personal opinion on the advisability of the creation of a research laboratory where urgent technical matters relating to the needs of our Navy could be studied successfully.

At the second meeting a special committee was appointed to submit a joint report. On this committee were, besides Mr. Edison, four other members. One of the other members of the committee is a man who has earned a national reputation in organizing and developing one of our largest mechanical industries. The second member is at the head of perhaps the largest and best endowed scientific research institution of the world; another is the chief of one of the most successful chemical and physical industrial research laboratories of this country; the fifth has devoted much of his life to private chemical research.

VARIOUS OPINIONS OF HOW RESEARCH SHOULD BE CONDUCTED

It was interesting to follow how the five members grouped themselves in accordance with their own point of view, dictated by their daily scope of action: The chemical or purely scientific members of this committee agreed pretty well on the kind of research laboratory they had in view, and although their suggestions had been written independently without consulting each other, their general recommendations as to the organization, equipment, and needed expenditures were fairly similar and relatively modest.

But their recommendations were mainly limited to a chemical and physical laboratory; they did not include the study of elaborate mechanical and technical problems which go far beyond the questions which are usually dealt with in chemical and physical research laboratories.

The two other members, on the contrary, wanted to prepare thoroughly for engineering problems of imme-

diate importance, the solution of which seems indispensable if the money of the Navy is to be spent to best advantage.

They set forth, from their own direct experience, how very expensive such engineering experimental work is likely to be.

Edison, for instance, pointed out the millions he spent in developing some of the details of his inventions; another member identified with the automobile industry stated that one single automobile concern here in the United States had found it necessary to spend half a million dollars in one year for experiments and research.

The modest estimate for a merely chemical and physical laboratory was thus snowed under by the irrefutable evidence of the much larger needs for a suitable mechanical or engineering department.

Of course, it was argued that the Navy possesses already several experimental stations at its different Navy yards, and at the Torpedo Station in Newport, aside from the different testing laboratories for the materials used for ordnance or ammunition; that, furthermore, the excellent laboratory facilities of the Bureau of Standards are available.

The answer to this was that each and every one of the present institutions were more necessary than ever, but were totally insufficient; furthermore, the full cooperation of all of them is needed; all this in view of the fact that, at present, the Navy of this country is facing unusual responsibilities.

EXPERIMENTAL WORK CANNOT BE POSTPONED UNTIL IT IS TOO LATE

If it is deemed urgent to be prepared for defense, then this defense involves problems the solution of which cannot be deferred indefinitely. If something has to be done, it must be done immediately—not in five or ten years hence, when it may be too late.

In all of our present scientific research laboratories, time seems of relatively little or no account; problems which cannot be solved to-day can be solved to-morrow or in ten years or during the next generations; but this is not the case with the problems connected with the contemplated defense of our country; the solution of these problems cannot be postponed. They demand immediate action.

Nor is the condition of our Navy similar to that of an industrial concern that can afford to take chances with machinery or equipment which is not strictly up to date, and still show some commercial success. For instance, recent events have demonstrated that there is no use building the best and newest fortresses against an enemy who possesses guns strong enough to demolish everything in existence.

Nor is there any chance of success in using the very best artillery at anything like equal chances if your adversary can do his scouting and range-finding with aeroplanes provided with reliable engines, while your aeroplanes are equipped with motors which give out at unexpected moments.

In our clumsy war with weak Spain, we went into the field with black powder when all other nations, even Spain, were equipped with smokeless powder. Why? Because we had postponed too long studying the chemistry of the subject.

The fact is that if we require a Navy at all, our Navy cannot afford to use anything but the very best and most efficient means of defense. Not to possess the very best might put us in the same absurd condition as the wooden navies of the world were in after our civil war had established the supremacy of the ironclad vessel.

RESEARCH MUST PREVENT THAT MONEY FOR DEFENSE SHOULD BE SPENT ON OBSOLETE OR INADEQUATE MEANS OF DEFENSE

The contemplated outlay for the Navy for the next five years, for new ships, aviation and reserve of munitions, amounts to about $500,000,000. These tremendous expenditures of money, in order to be of real value, ought to be made as efficient as possible. All doubtful and inferior devices must be eliminated by direct experiment, by research and tests, *before* it is too late to remedy them.

This requires accelerated action; in fact, Mr. Edison's personal opinion was that research and laboratory work in this instance "should go on night and day without intermission" instead of the usual easy-going short-day plan followed in laboratories.

If one single automobile concern in the United States finds it to its advantage to spend in one year half a million dollars on testing, research, or experimentation, how much more important is the business of the United States Navy, where money not spent wisely is better not spent at all, because then at least we shall not have the illusion that we are equipped for defense, when we have merely lost our money on antiquated devices.

MILLIONS OF DAMAGE TO OUR FLEET ON ACCOUNT OF CORROSION OF CONDENSER TUBES

Without mentioning any spectacular problems of modern warfare, it might be stated that such a prosaic detail as the corrosion of condenser tubes of our warships, involves an annual damage of about $2,000,000. If $1,000,000 were spent on research on this problem alone, with the result of reducing the damage to one-half, the total outlay would be compensated in a few months' time, aside of the important fact that our fleet would be stronger because less of our ships would be unavailable for service.

It was brought out that there was little use in spending so many millions on flying machines as long as there was any doubt on the reliability of their engines, and until an absolutely well-tried and standardized engine had been developed. To accomplish this experimental work in a period of a few years would cost quite some money; but to do this rapidly, within a few months, before order is given to build these flying machines, requires enormous outlays of money, alongside of the indispensable engineering talent.

THE NAVY SHOULD FIND IT PROFITABLE TO SPEND AS MUCH FOR EXPERIMENTATION AS ANY PRIVATE INDUSTRIAL CONCERN

Another member brought out the fact that even conservative industrial enterprises found it necessary and profitable to spend at least 2 to 5 per cent of their sales on research and experiments. At this rate, the contemplated expenditure of $500,000,000 in five years, would certainly warrant an expenditure of at least five million for research during that period.

Money for this purpose wisely used, ought to do so much good to the Navy as to increase its efficiency by the value of several battleships costing considerably more. Mr. Edison's arguments were particularly eloquent when he enumerated the enormous expenditures for research in his own laboratories.

In this discussion everybody seemed to be well in accord with the general idea that whatever expenditures were recommended, the contemplated work should be carried out under immediate supervision of the Navy; that this work should not be started all at once—full blast—but should be extended gradually, as fast as circumstances demand it.

In view of all this, two policies were open for obtain-

ing the necessary appropriations—the old time-honored trick of asking from Congress first an appropriation of a few thousand dollars, knowing very well that this would be insufficient, then after awhile ask an additional appropriation and keep on nagging and asking at various intervals.

But the members of the advisory board thought it a more honest policy to state the facts as they saw them and to confront the Secretary of the Navy with the probable maximum expenses for research and experimentation, commensurate to the five years' naval building program now under contemplation. The five-million dollar budget for experimental work to be expended during those five years, or about one million a year, may strike the uninitiated as needlessly large, although it is only about what some industrial enterprises have found necessary to spend on their own experimental work.

LET BLUNDERS BE COMMITTED IN A SMALL EXPERIMENTAL WAY INSTEAD OF ON A LARGE SCALE

But if the nation does not want to go to the expense of developing the latest and most efficient means for defense at the lowest cost by obtaining the necessary information through preliminary experiments, instead of committing mistakes on a large permanent scale; or if our country wants its Navy to keep on building its ships or other means of defense, as were good enough in the past, regardless of the fact that modern war requires the very latest and the most efficient available devices, then let us not be astonished if after incomparably more money has been spent for increased armaments, we find that we are loaded with means of defense which have become obsolete in the meantime and are good for the junkheap of antiquated equipment.

The foregoing is a brief résumé of various arguments which were submitted by some members of the board, and this is the first time that this discussion has been reported in public. Let us hope that its publication may help to dispel some of the ideas of the public which imagines that the board contemplates the immediate erection of a "$5,000,000 laboratory building, where the members of the Naval Consulting Board can experiment to their hearts' content in company with long-haired inventors."

As Mr. Edison expressed it picturesquely: "The money should be spent not on buildings, but on a national junkshop," where means of defense can be tried out first, at relatively small cost so as to learn how to get the most and very best for the money, and so as to avoid making expensive and dangerous blunders on a wholesale scale.

ADMIRAL MELVILLE TWELVE YEARS AGO STRONGLY URGED EXPERIMENTAL WORK IN THE NAVY

More than twelve years ago one of the most distinguished officers of our Navy, Admiral George W. Melville, urged strenuously the necessity of naval engineering experiments; his well based arguments published in the *Proceedings* of the Engineers' Club of Philadelphia (Vol. XX, No. 3, July, 1903) brought out the fact that expenditures for experiments are the best means for avoiding expensive mistakes. What he said then, sounds even more convincing to-day.

The following quotations are taken from his paper:

"The hulls and machinery of these five battleships will cost approximately $20,000,000. The armor, armament, and equipment will require an additional outlay of $15,000,000; so that the actual cost of these battleships will probably be about $7,000,000 each. The annual depreciation of each of these vessels from the time they are launched, taking into consideration wear and tear as well as loss in fighting value, will be at least 4 per cent of their actual cost. The expense attending the establishment of the proposed experimental station, including its operation for several years, will thus be but little more than the annual loss resulting from corrosion, mishaps, and depreciation of military appliances of two of these floating fighting machines."

"The success of Germany can be accounted for only by recognizing the fact that study, reflection, and research must have been expended in the preparation of plans, in the building up and the organization of the shipyards, and in laying out and carrying on the work of construction. It was the high appreciation of the value of original investigation, coupled with experimental work, that has caused Germany to advance progressively and successfully."

"Where research had not been conducted, disappointment resulted from the construction of vessels which were either faulty in design, ill-suited for the purpose intended, or upon which an inferior quality of work had been expended."

"The problem as to whether or not in-turning screws are detrimental to manœuvering qualities would have been solved many years ago if the work planned by Mr. Isherwood had been continued. Our increased knowledge of the theory and practice of screw propulsion since the Isherwood experiments is due, however, almost wholly to the work of Froude, conducted for the British Admiralty. This is confirmatory evidence that such important and difficult work can only be undertaken by official or civilian experts who are able to call upon government resources for data and information. It requires government investigation to solve important problems relating to the powering of vessels, since valuable and far-reaching experiments upon this subject require the use of ships as well as the services of a large number of reliable and competent persons to collect the data requisite for the determination of absolute results.

"If it be true that the battleship of one generation is the junkheap of the next, then an economical race like the German is pursuing a wise policy in conducting experimental research and investigation in the direction of finding out how the weak links in the naval chain can be strengthened.

"Experience has shown that the German engineering laboratories are more than a good paying investment, for there is not an expert in that empire familiar with the work being done at these laboratories who does not beleive that their destruction would be a greater national calamity to the navy and the nation than the loss of one of the battleships of the home squadron. The warship could be replaced in four years. It would take six years to rebuild and put in effective operation the complete installation for conducting experimental research that has been developed and perfected at the Charlottenburg and Dresden technical college.

"There is probably not an eminent naval or mechanical engineer in America or England who has given consideration to this question who is not also of the opinion that the establishment of a national experimental laboratory for naval purposes will vastly contribute to military strength. Probably the majority of these experts also believe that such an institution would eventually contribute more to actual naval strength than the building of a battleship. One does not need to possess vital imagination to realize that much is contributed to the fighting strength of a navy by carrying on research along engineering lines, and thus preventing the design, construction, and installation of appliances that are ill suited for the purposes intended.

"The cost of maintaining a battleship in commission will approximate $1,000 per day, and warships have been tied up for weeks on account of the corrosion of a few hundred dollars' worth of boiler tubes. It will repay the nation for the cost of an experimental station if the staff of the laboratory will simply cause increased length of life of both boiler and condenser tubes."

Standardization of Metallurgical Units.—In the preliminary report of the Committee on Standardization of the Mining and Metallurgical Society of America (page 818 of our issue of Nov. 15) in the paragraph on "mesh of wire cloth" there is an error in regard to the relation of openings in the Tyler standard screen scale, to which the W. S. Tyler Company of Cleveland has kindly called our attention. The paragraph states: "This furnishes a standard screen scale in which the area of each successive opening in the scale is double that of the second preceding." It will be seen that with the ratio of the series the square root of 2, the areas of successive openings double the next preceding, instead of the second preceding.

The Cyanide Plant of the Baker Mines Co., Cornucopia, Oregon

BY ROBERT M. KEENEY

Formerly mill superintendent, Baker Mines Co.

The mill of the Baker Mines Co. was built in the summer of 1914 to treat the ore of the Last Chance mine, formerly owned by the Cornucopia Mines Co. The camp of Cornucopia is situated seventy-five miles northeast of Baker City, Ore., in Baker County. The nearest railroad station is Robinette on the Snake River branch of the Oregon Short Line Railroad. The roads are fair, and the camp is accessible by automobile in the summer, but all freight has to be hauled by wagon or sled. The winters are not cold, but there is a heavy snowfall with all the resulting obstacles to mining. All of the mines of the camp are in a snowslide country, making a careful choice of sites for buildings essential.

The district is very rough and precipitous with a considerable quantity of timber, being a part of the Minam national forest reserve. The rough character of the mountains is shown in Fig. 1 and Fig. 2. In Fig. 1 the mine is at the horizontal white streak at the extreme upper left hand corner of the picture. There are possibilities of numerous small high-head water-power developments in the neighborhood on Pine Creek and its branches, and at a greater distance on other creeks. Power could also be obtained from the Oxbow plant of the Oregon-Idaho Power Co. on the Snake River, thirty miles distant. The Baker Mines Co. mill is at an elevation of about 5325 ft., and the mine at 7000 ft.

The character of the ore milled is quite variable. Depending on the part of the mine from which it comes it may be oxidized, with some free gold, or a heavy sulphide ore. Most of the sulphide is pyrite, with smaller amounts of sphalerite, galena and chalcopyrite. The gangue is quartz. Pockets of telluride ore occur, and there is some copper present in an oxidized form. The battery heads assay from $12 to $16 per ton. The ratio of gold to silver is variable, being from three parts of silver to one part of gold up to a five to one ratio.

FIG. 1—MILL OF BAKER MINES CO., CORNUCOPIA, ORE.

FIG. 2—MINE BUILDINGS AND LOADING TERMINAL OF THE TRAMWAY

The copper contents of the ore milled have varied from zero to 1.75 per cent, and have averaged for a month 0.21 per cent. At first the copper gave considerable trouble, due to fouling the solutions, but now chiefly causes a higher cyanide consumption and a higher zinc dust consumption. The gold extraction is not decreased much when the copper content increases, but the silver extraction is generally lower, probably due to more of the silver being in the form of a complex sulphide with copper.

Tramway

A Bleichert aerial tramway, erected by the Trenton Iron Works, conveys the ore from the lower tunnel of the mine to the mill. All supplies and miners go to the mine over the tramway except in summer when the mine is accessible by road. The upper terminal of the tramway is seen at the right in Fig. 2. Fig. 3 shows the lower terminal at the mill.

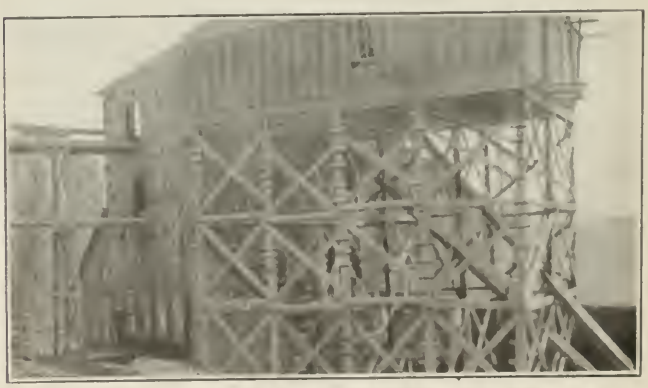


FIG. 3—DISCHARGE TERMINAL OF TRAMWAY AT THE MILL

When operated at full speed the tramway has a capacity of 15 tons of ore per hour. There are 24 buckets, each holding 6 cu. ft., or 625 lb. of ore. At full capacity the buckets run with the distance between them 625 ft., an interval of 75 sec., and speed of traction rope 500 ft. per minute. The length of the tramway is 5500 ft., with the loading terminal at 1675 ft. higher elevation than the discharge terminal. Between the two terminals there are two towers and a tension station. The span between the tension station and the discharge terminal at the mill is over 3200 ft. long, which is said to be the longest aerial tramway span in the United States. The track cable is of three sizes, 1⅜-in. diameter, 1⅛-in. diameter and ⅞-in. diameter. The tramway develops 21 hp. It was erected under very difficult conditions in a rough country, but even with the long span has given no trouble in operation, and after one winter appears to be as intended, immune from snowslides.

Mill Buildings

The buildings are of wood frame with corrugated iron roof and siding. Concrete foundations and retaining walls are used throughout. The mill buildings are shown in Figs. 1, 4 and 5. In Fig. 4 the main mill building and tramway terminal are at the left, and the precipitation building and store house on the right. The tramway discharges into the crusher over the ore bin at the head of the mill.

The mill is built on a hill side with a 15-deg. slope. The precipitation presses, barren solution tanks, melting furnaces and assay office are in a separate building about on the level of the ore bin.

Mill Equipment

In designing the mill several factors influenced the process and equipment, more than the idea of obtaining a very high recovery of values. The principal of these was the amount of power which could be developed locally without a considerable expenditure. If there had been sufficient power available without large outlay, it is probable that an all-sliming plant with tube mills would have been built instead of a sand and slime plant. On ore similar in a general way the Cornucopia Mines Co. obtains a 90 per cent extraction by the all-sliming process. The designers of the mill, John M. Baker and Paul W. Gaebelein, expected to eventually get an 85 per cent recovery, and a little better is now being obtained.

The mill equipment includes the following:

Grizzly—1½-in. openings.

Crusher—No. 3 suspended type Austin gyratory crusher. Speed, 425 r.p.m., requiring 20 hp. Capacity, 10 to 20 tons per 24 hr. through 2½-in. ring.

Battery Feeders—Four supported type Challenge feeders.

Stamp Mill—Twenty 850-lb. stamps. Stems, 3⅜ in. in diameter by 14 ft. long. Two key tappets later replaced by three key tappets. Bossheads, 8¾ in. in diameter by 17 in. long. Chrome steel shoes, 8¾ in. in diameter by 9 in. high; weight, 165 to 170 lb. Cast-iron dies, 7⅜ in. high by 8½ in. diameter steel and iron fake bottoms 9 in. square by 3 in. thick. Four mortars: base, 4 ft. 6 in. by 2 ft. 3 in. Demarest steel guides with the stems 9¼ in. centers. Camshafts, 5⅜ in. in diameter by 14 ft. long. Order of drop, 1-3-5-2-4. Drops per minute, 102. Height of discharge, 2 in. Drop, 7 in. Twenty-five mesh screens. Duty per stamp day, 3.4 tons. Power required, 40 hp.

Amalgamation Plates—Four silver-plated copper plates, 54 in. by 7 ft. 6 in. Grade, 2 in. per foot. Divided into two parts by strips to avoid hanging stamps when cleaning up or dressing the plates.

Dorr Classifier—Model C duplex Dorr classifier with steel tank.

Leaching Tanks—Three fir tanks, 30 ft. in diameter by 10 ft. deep, with 3-in. staves. False bottoms covered by cocoa matting and canvas. Four 14-in. iron circular discharge gates in the bottom of each tank.

Sand Distributors—Three revolving-arm sand distributors.

Dorr Thickeners—Two thickeners in wooden tanks, 30 ft. in diameter and 10 ft. deep, with 3-in. staves. Arms revolving at 1/10 r.p.m. One thickener in wooden tank, 20 ft. in diameter by 10 ft. deep, with 3-in. staves. Revolving at 1/5 r.p.m.

Dorr Agitators—Three-inch wooden tanks, 20 ft. in diameter by 16 ft. deep, with 3-in. staves.

Portland Filter—One filter with drum, 14 ft. long by 9 ft. in diameter. Revolving at 1/6 r.p.m.

Gould's Suction Vacuum Pump—One 14 in. by 10 in.

Gould's Triplex Pumps—Two pumps, 4 in. by 6 in.

Swaby Centrifugal Pumps—One 3-in., one 2-in.

Merrill Clarifying Press—Ten-frame, 36-in. sluicing clarifying press. Capacity, 210 tons clarified solution per 24 hr.

Gold Solution Tanks—Three fir tanks, 20 ft. in diameter by 10 ft. deep, with 3-in. staves.

Merrill Precipitation Presses—One 16-frame, 36-in. press and one 8-frame, 36-in. press. Combined capacity, 300 tons clarified solution per 24 hr.

Barren Solution Tanks—Two fir tanks, 20 ft. in diameter by 14 ft. deep, with 3-in. staves.

Merrill Zinc Dust Feeders and Emulsifiers—Two of each.

Furnaces—One 3-muffle drying furnace. Two Case oil-fired furnaces taking No. 135 crucible.

Water Wheel—One 6-ft. Pelton water wheel.

Air Compressor—Sullivan Class WG3, 14 in. by 12 in., single-stage belt-driven air compressor; 342 cu. ft.

FIG. 4—MILL BUILDINGS AND TRAMWAY TERMINAL

FIG. 5—LOWER END OF MILL

free air per minute; 20 lb. per square inch pressure. Requires 26 hp.

Power

The mill is belt-driven directly from a main line shaft which is belted to the Pelton wheel. The hydraulic installation consists of a pipe line 4000 ft. long, with 1036 ft. of wooden flume feeding the pipe from the east fork of Pine Creek. There is 1000 ft. of 10-in. 12-gage spiral riveted pipe with bolted joints, 1000 ft. of 10-in. 14-gage spiral riveted pipe with bolted joints, and 2000 ft. of 11-in. 16-gage spiral riveted pipe with slip joints. The actual head of water on the wheel is 537 ft., and the gage pressure at the wheel is 221 lb.

The maximum power developed is about 165 hp., but it takes only about 120 hp. to run the mill. After installation of the power plant it was found there was enough water available for development of as much more power, and another wheel is now being installed.

Operation

A flowsheet of the operation of the mill is shown in Fig. 6.

The ore is dumped from the tramway buckets on to a grizzly set with 1½-in. spaces, from which the undersize goes to the battery bin and the oversize to an Austin gyratory crusher, crushing to 1½ to 2½-in. size. Each battery of five stamps is fed from the bin by a Challenge feeder.

Crushing is done in a cyanide solution of 1.5 lb. KCN per ton strength and 1.0 lb. per ton CaO alkalinity. Lime is added in one battery. Ton cap screens of 25 mesh are used.

After passing over the plates the pulp, consisting of about five tons of weak solution to one ton of ore, passes to a duplex Dorr classifier, where the sand and slime are separated. The sand is about 60 per cent of the total ore and the slime 40 per cent.

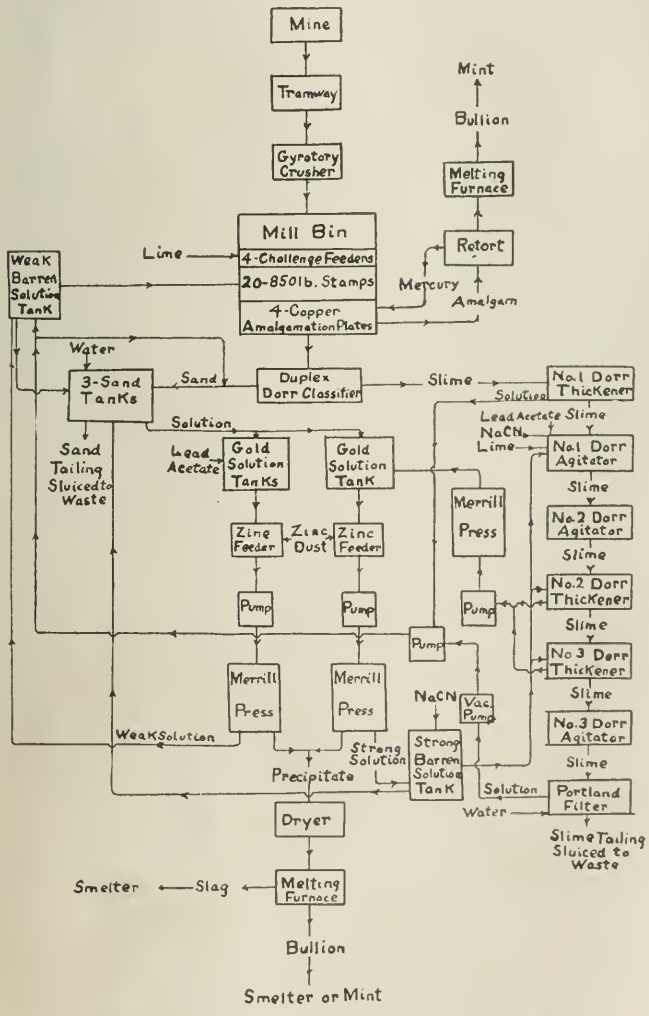


FIG. 6—FLOW-SHEET CYANIDE PLANT OF BAKER MINES CO.

The sand, containing about 25 per cent moisture, is diluted with weak solution as it leaves the classifier, and is lifted by an air lift which discharges to the sand distributors at each leaching tank. The sand is leached with a solution containing 3 lb. per ton KCN and 1 lb. per ton CaO, called the strong solution. The first wash is with 1.5 lb. KCN solution from the weak storage tank, and the final wash is with water. Sodium cyanide is used to keep the solutions up to the required strength. The sand is discharged from the tanks by sluicing with high pressure water into a flume going to a tailings dam. Solutions percolating from the leaching tanks are turned into the weak or strong gold solution tanks as seems advisable and precipitated in Merrill presses. All of the strong solution is precipitated and most of the weak.

The slime leaves the Dorr classifier at a consistency of ten parts of liquid to one of solids, and flow by gravity into No. 1 Dorr thickener, a 30-ft. thickener. The overflow from No. 1 thickener goes to a 3-in. centrifugal pump, which pumps what solution is needed to the sand lift and the balance to the weak storage tank. The pulp from No. 1 thickener, of a 1 to 1 consistency, is lifted to a launder discharging into No. 1 agitator. In the agitator the pulp is diluted with strong solution to maintain a ratio of liquid to solids of 2.5 to 1. Sodium cyanide and lime are added to keep the agitator solution of 3 lb. KCN strength and 1 lb. CaO alkalinity.

The pulp passes from No. 1 agitator to No. 2 agitator and then to a 20-ft. Dorr thickener. Here dilution with strong solution is made 3.5 to 1. The overflow from this thickener passes into the feed box of a 2-in. centrifugal pump, which pumps through a Merrill clarifying press and discharges into the strong gold solution tank. In No. 2 thickener the pulp is thickened to 1.5 to 1, and raised by an air lift to No. 3 thickener, a 30-ft. thickener. In this thickener there is further dilution with strong solution to a ratio of 4 to 1. The overflow from the thickener is pumped through the clarifying press. The pulp is thickened to 1 to 1, and discharges by gravity into No. 3 Dorr agitator, which is used as a storage agitator, and at first was run without air agitation, simply mechanical agitation, but later the pulp was aerated as it appeared to increase extraction.

The pulp runs from the bottom of No. 3 agitator to the Portland filter. The slime from the filter discharges into the tailings flume, and the solution goes to the 3-in. centrifugal pump and enters the weak mill solution. The slime was at first washed at the filter with only one water spray, but now has several.

There is one strong gold solution tank and two weak gold solution tanks. One of the weak solution tanks is used chiefly to receive muddy solution from the leaching tanks when a tank is beginning to be filled, and when the clarifying press is being cleaned. The solution from this tank is precipitated only after it has settled well.

The strong solution containing about 2.5 lb. KCN and 1 lb. CaO per ton is pumped through a 16-frame Merrill precipitation press, which discharges barren solution to the strong storage tank, where it is strengthened with sodium cyanide to 3 lb. KCN per ton.

The solution from the weak gold solution tanks is pumped through an 8-frame Merrill press which discharges barren solution to the weak storage tank. No cyanide is added in this tank but enough is added in the weak gold tanks to keep the strength at 1.5 lb. KCN per ton before precipitation, as experience has shown that with much lower strength there is not a satisfactory

precipitation. Some lead acetate is added in the weak gold tanks and also in No. 1 agitator.

The precipitation presses are cleaned up three times per month, and the precipitate dried in a muffle furnace. The dried precipitate is melted in Case oil-fired tilting furnaces, giving a low grade gold-silver-copper bullion as a product.

Amalgamation

Amalgamation is carried on in cyanide solution with poor efficiency of amalgamation, as is usually the case. While extraction by amalgamation is not high, amalgamation serves a useful purpose in that it catches the coarse gold not extracted by the cyanide solution. Even with amalgamation there is some loss of coarse gold as was shown by a concentration test on the tailings.

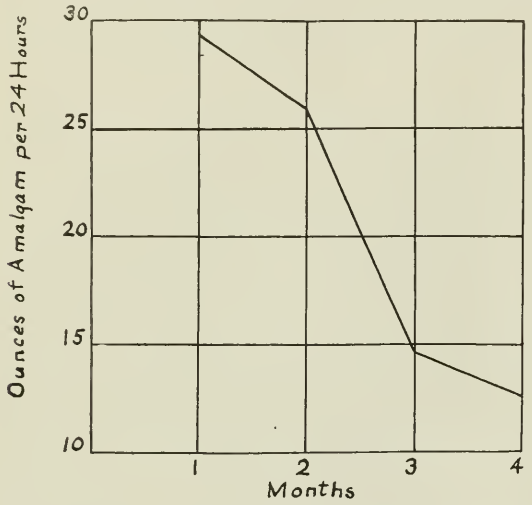


FIG. 7—EFFECT OF AMALGAMATION FOR FOUR MONTHS IN CYANIDE SOLUTION ON RECOVERY OF AMALGAM

During the first month and a half of operation of the mill oxidized ore was milled with the production of a considerable amount of gold by amalgamation. At the end of that period the ore became strongly sulphide with a small amalgam production. In the four months following the treatment of oxidized ore, the average production of amalgam was 20 oz. per day of an average value of $2.62 per ounce.

During the first two months of operation the plates were dressed once per shift, or three times per day. Later they were dressed six times per day, and scraped as clean as possible in the daily clean-up. In spite of this the plates became hard and the recovery by amalgamation dropped off, the percentage of total extraction by amalgamation falling from 9 per cent to 5 per cent.

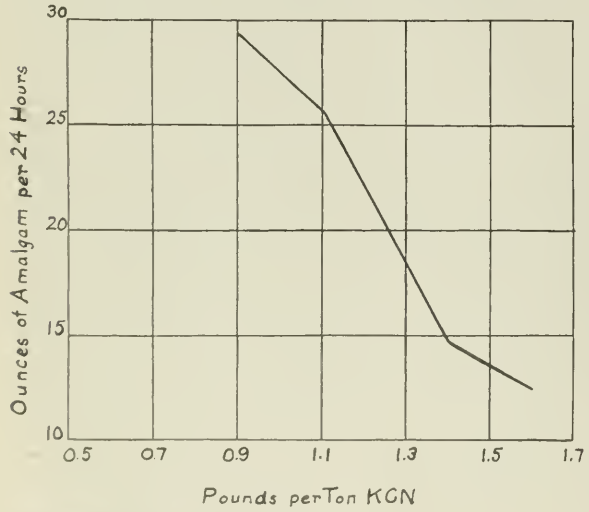


FIG. 8—EFFECT OF STRENGTH OF CYANIDE SOLUTION ON RECOVERY OF AMALGAM WHEN AMALGAMATING IN CYANIDE SOLUTION

The effect of the cyanide solution in hardening the plates and decreasing amalgamation from month to month is shown in Fig. 7. Fig. 8 shows the drop in amalgamation caused by the increased strength of the battery solution. In starting the mill the weak solution was allowed to build up gradually, cyanide being added only to maintain precipitation. The value of ore milled remained about the same during these four months, not varying enough to influence the value of the data. In the second month, where the value of the battery heads increased $2.50 per ton, the efficiency of amalgamation still continued to drop. The tonnage milled varied between 61.8 tons per day and 67.1 tons, the largest tonnage being handled in the fourth month when the average ounces of amalgam per day was at its lowest.

AMALGAMATION IN CYANIDE SOLUTION

Month	Average Value Battery Heads per Ton	Average Ounces Amalgam per Day	Average Strength Battery Solution KCN Pounds per Ton
1	$13.66	29.2	0.9
2	16.22	25.9	1.1
3	13.58	14.8	1.4
4	13.35	12.5	1.6

Leaching

The Dorr classifier delivers a sand product containing 20 to 25 per cent moisture, of which a typical sieve analysis is the following:

		on 40	20.5	per cent
through	40	on 60	24.5	per cent
through	60	on 80	18.0	per cent
through	80	on 100	21.0	per cent
through	100		14.5	per cent

The sand is diluted with weak solution to 5 to 1 before going to the air lift, which delivers it at the sand distributors in the leaching tanks. The use of an air lift for the sand instead of a sand pump has proved very satisfactory, the lift giving no trouble and showing no wear except for one nipple, which is replaced about every four weeks. The lift piping is 2½ in. in diameter. The height of lift is 14 ft., with a submergence of 17 ft. The lift does not discharge into launders, but its piping is continued to the center of each leaching tank. Distributors of the revolving-arm type are in use, made by two concerns, but neither operate satisfactorily because of the small tonnage handled.

In filling a tank the drain valve is left open for several hours, when it is kept closed until the tank is partly filled with solution, so that the sand settles in solution. The solution overflow goes to the 3-in. centrifugal pumps.

When full the sand is leveled and strong solution containing 3 lb. KCN and 1 lb. CaO per ton is turned on so as to keep the surface covered for about 12 hr. Then the tank drains for 12 hr. and the cycle is repeated. The strong solution treatment lasts five days, when weak solution is used for washing, followed by a water wash, both extending over two to three days. The draining solution usually runs into the weak gold solution tank for a day, when it is turned into the strong sump, and finally back into the weak after the weak solution and water washes are applied. The turning point in KCN strength depends chiefly on the tonnage of strong and weak solutions.

The tank charges average 180 tons, and when well drained are sluiced out to the tailings flume with a high pressure water hose, one tank being discharged by a man in about 7 hr. The four discharge gates in

each tank are not well located for sluicing, as shoveling and tramming was first used, but discarded when it was found possible to give a tank only three days' treatment with 3 lb. solution. By this change the cost of removal of tailings was reduced from 10 cents per ton to 3.5 cents and the extraction much improved.

Below are tabulated the results of solution samples taken from a tank during its cycle of strong solution, weak solution wash and water wash. The sample taken 24 hr. after the first application of 3-lb. solution is still low in cyanide, but its value shows the dissolving effect of the 1.5-lb. solution during the filling of the tank. These assays are shown graphically in Fig. 9.

GOLD BEARING SOLUTIONS FROM LEACHING SANDS

Hours After First Bath of 3-Lb. Solution	Pounds KCN per Ton	Pounds CaO per Ton	Ounces Gold per Ton	Ounces Silver per Ton	Per Cent Copper
24	1.3	1.2	0.166	0.19	0.088
48	1.9	1.3	0.134	0.43	0.102
72	2.0	1.0	0.126	0.48	0.099
96	2.0	0.9	0.116	0.53	0.105
120	1.8	1.0	0.102	0.42	0.101
144	1.8	0.8	0.086	0.27	0.092
168	0.9	1.0	0.011	0.17	0.037
192	0.6	0.6	0.022	..	0.024

The soluble values in the sand tailings amount to about 10 cents per ton gold, and 0.15 lb. KCN per ton of ore. A little more washing would cut down losses, but time is not available. The tailings from the above tank contained 0.07 oz. gold per ton and 0.89 oz. silver, or $1.86. The sand tailings average from $1 to $3 per ton, depending on the grade of the heads. The sand is 60 per cent of the ore and the slime 40 per cent, but the total value of sand and slime heads are about equal, as the slime contains 50 per cent more of the values than the sand.

Slime Treatment

The Dorr classifier delivers a slime product of the following sieve analysis:

	on 100	3.31 per cent
through 100	on 150	2.88 per cent
through 150	on 200	8.07 per cent
through 200		85.80 per cent

This slime is a very fine slime and not as sandy as slime from fine grinding. This makes the operation of the thickeners and agitators easy, as the slime does not pack after a shut down. It is, however, a rather difficult slime for the filter, and makes cleaning the filter once a week necessary, although the filter is operated only 8 hr. per day.

The slime assays 0.6 oz. per ton gold, 5 oz. silver and 0.15 per cent copper, as compared with sand from the same ore containing 0.45 oz. gold, 2.5 oz. silver and 0.10 per cent copper. The sulphide is also higher in the slime. The slime tailings contain from $1.50 to $3 per ton, a considerable part of which is silver, on which the extraction is very low. With the single water spray on the filter, as originally installed, the soluble losses have been high at times, and never under 5 cents per ton.

Precipitation

Both domestic and foreign zinc dust have been used for precipitation. The domestic has caused trouble at times because of the metallic shot it contains, which clogs the emulsifiers unless the zinc dust is carefully screened. Also the domestic zinc dust is not well packed, resulting in considerable loss in shipment, which is not the case with foreign material.

At times the zinc dust consumption is high because of copper in solution, and it varies from 0.7 lb. to 1.25 lb. per ton of ore. During a period in which the zinc dust consumption was 0.73 lb. per ton of ore, the consumption per ton of 1.5 lb. KCN solution precipitated was 0.28 lb., and per ton of 2.5 lb. KCN solution precipitated was 0.15 lb. For all solutions precipitated the zinc dust consumption was 0.2 lb. per ton of solution. Per ton of ore milled 3.4 tons of solution were precipitated. Of this solution 1.2 tons was weak solution and 2.3 tons strong solution.

In starting the mill no cyanide was added to the battery solution or weak solution until it began to carry values picked up in washing. When it became necessary to precipitate, an attempt was made to use as little cyanide as possible because of the high price at that time. Lead acetate was used to assist precipitation, but it was eventually found that satisfactory precipitation could only be obtained regularly when the weak solution contained 1.5 lb. KCN per ton. Cyanide is now added at the weak gold solution tank to bring the strength to 1.5 lb. before precipitation.

No cyanide is added to the strong gold solution tank which averages 2.5 lb. per ton before precipitation. About 0.18 lb. of lead acetate is used per ton of ore. Of this 0.04 lb. per ton of ore is added in the weak gold solution tank, and the balance at the agitators.

The difficulties encountered in attempting to precipitate values from solution of low cyanide content are shown in the following table and in Fig. 10. The results given are averages of several months' operation:

ZINC DUST PRECIPITATION FROM WEAK CYANIDE SOLUTION

Pounds per Ton KCN in Solution	Per Cent of Total Value Precipitated	Pounds per Ton KCN in Solution	Per Cent of Total Value Precipitated
0.65	0	1.3	91.4
0.7	0	1.4	94.6
0.8	43.4	1.5	94.9
0.9	64.2	1.6	96.6
1.0	57.8	1.7	98.0
1.1	85.7	1.8	95.0
1.2	89.9	1.9	97 9

Effect of Copper on Extraction

The percentage of copper in the battery heads has varied from zero to 1.75 per cent. For a period of a month it has averaged 0.21 per cent. At first the copper gave considerable trouble, and resulted in a lower extraction, especially of the silver, which seemed to be

FIG. 9—GOLD, SILVER, COPPER, KCN AND CaO CONTENTS OF SOLUTION DURING A LEACHING CYCLE

present in a more complex sulphide form when copper was high. Lead acetate was tried to assist solution, but the character of the ore is so changeable that it is impossible to attribute improved extraction entirely to it.

During the first months of operation cyanide was used as sparingly as possible, costing 40 cents per pound of NaCN, because it was believed that with the low-grade ore being milled it was cheaper to get a lower extraction with weaker solutions than to aim for a higher extraction with increased cyanide and zinc dust consumption, because of the copper going into solution more easily. The cyanide consumption varied from 1.25 to 1.6 lb. NaCN per ton and the zinc dust consumption from 0.75 to 1.0 lb. per ton while copper-bearing ore was milled.

The copper in the ore does not seem to affect the gold extraction much, but does lower the silver extraction. It was found that by keeping the solutions clean by use of excessive amounts of zinc dust at times when the copper was highest, there was little effect by the copper on the total extraction. When the solutions contain around 0.05 per cent copper no difficulty is experienced either in extraction or precipitation. The precipitate contains much copper and gives a very base bullion in the simple melting process used.

Operating Data and Costs

Tables I and II give a summary of operating data and costs for a certain period of operation. The costs do not include melting. The labor requirements for the mill are: One crusherman, one amalgamator, two batterymen, three solution men, one night foreman, one mechanic, and two laborers.

Table I—Summary of Milling Record

Average value per ton	$13.35
Average tons per day	66.1
Per cent of possible time run	97.5
Cyanide consumed per ton of ore, pounds	1.27
Lime consumed per ton of ore, pounds	4.29
Zinc consumed per ton of ore, pounds	0.73
Lead acetate consumed per ton of ore, pounds	0.18
Mercury consumed per ton of ore, ounces	0.19
Per cent extraction, gold, bullion and tails	87.23
Per cent extraction, silver, bullion and tails	43.23
Total per cent extraction, bullion and tails	80.44

Paul W. Gaebelein, the present mill superintendent, has kindly made the following statement regarding changes in plant practice since May, 1915:

"1. *Strength of Cyanide Solutions.*—It was decided that, in order to obtain a better extraction of the silver and possibly the gold, the solutions would have to be strengthened, and this was done starting May 1. The strong solution was raised to an average of 5 lb. per ton KCN, and the weak solution to 2.5 lb. KCN per ton.

Table II—Distribution of Milling Costs

	Per Ton of Ore
Agitation and thickening	$0.052
Amalgamation	0.023
Assaying	0.117
Clarifying and precipitation*	0.233
Classifying	0.009
Cleaning up mill	0.043
Crushing	0.143
Cyanide**	0.509
Experimental	0.080
Filtration	0.038
General mill expense	0.100
Heating	0.058
Leaching	0.041
Lighting	0.031
Neutralization	0.055
Power	0.002
Pumping solutions and handling pulp	0.046
Sampling	0.025
Shoveling in bins	0.004
Stamping	0.289
Superintendence	0.143
Tailings disposal	0.037
Watchman	0.025
Total	$2.103

*Zinc dust, 22 cents per pound.
**Sodium cyanide, 40 cents per p

By adding cyanide to the flow of pulp entering the agitation tanks, the strength of solution in the agitators was kept at about 3.5 lb. KCN. The result of strengthening the solutions became apparent at once. The gold extraction has increased to 89 per cent and the silver extraction to between 50 and 55 per cent. The consumption of cyanide also increased, but not to a great extent. The normal consumption with the strengths of solution given above and with an average value of ore of $24 per ton, averages 2.5 lb. per ton milled.

"2. *Amalgamation.*—The plates at the battery were retained. Some experiments were made with a view to amalgamating the sand tailing as it was discharged from the leaching vats, but the results showed that this could not be done and a saving made which would justify the removal of plates at the battery. At present the plates save a varying amount of free gold. The average for the last four months may be taken at 12 oz. of amalgam per day of an average value of $5.50 per ounce, or a saving of approximately $1 per ton of ore milled.

"3. *Slime Treatment.*—Experiments were being conducted in this department which may be outlined as follows: The filter is served by a 20-ft. by 16-ft. Dorr agitator used as a stock tank. This agitator was being run full, and the increased extraction by this method over the former method of keeping the pulp level lower was noted. The increased agitation showed a saving of approximately 75 cents per ton, accounted for by the fact that the pulp receives approximately 8 hr. longer agitation, and the barren, strong solution comes in contact with the pulp just before entering the agitator.

"4. *Filtration.*—The Portland filter in use gives excellent satisfaction. The washing of the cake, however, was not as good as could be obtained, and to increase the efficiency at this point three lines of spray nozzles were installed. Each line has three nozzles, which force the water under pressure into the cake, and which keep the entire surface of the cake covered with a fine film of water. The use of the sprays has lowered the dissolved loss in the cake considerably, and by manipulation of the nozzles the solutions are easily kept in balance.

"5. *Free Gold in Sand Tailings.*—The sand tailing has been subjected to amalgamation as noted previously. The results have been rather negative. In looking for the reasons for this it was found that the free gold in the tailing was coated and very rusty. For this reason it probably escaped the battery plates. Determinations as to the amount of free gold being lost in

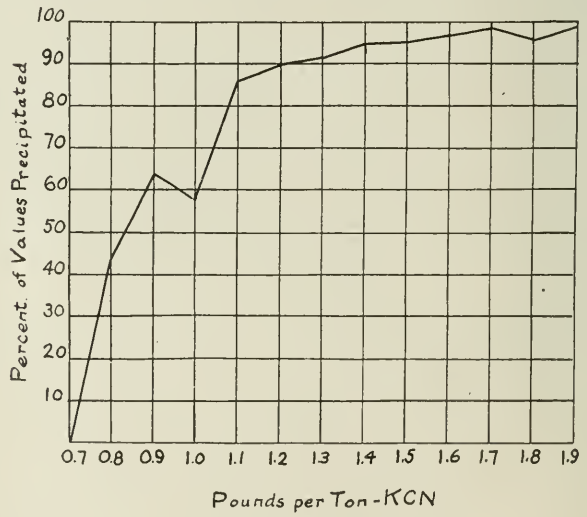


FIG. 10—EFFECT OF STRENGTH OF SOLUTION ON PRECIPITATION OF GOLD AND SILVER FROM CYANIDE SOLUTIONS WITH ZINC DUST

the sand tailing are now being made. The amalgamation of the tailing has shown an average recovery of 2.5 cents per ton of sand. This would tend to show that the loss in the sand tailing in free gold is something over 3 cents per ton.

"6. *Extraction.*—The extraction at the present time, on ore averaging $24 per ton, is 85.5 per cent. With the grade of the ore at $20 or over, the ore carries a very considerable amount of easily soluble copper, and this interferes considerably. With a little lower grade of ore, and a consequent lower copper content, it is expected that the extraction will show an improvement over the figures given above."

Metastability of Metals

BY A. VOSMAER

In continuation of the article on the same subject in the issue of Sept. 1 of this journal, on the metastability of bismuth, antimony, potassium and copper, I shall now give a brief account of the publications of Prof. E. Cohen of the Van't Hoff Laboratory, Utrecht, in the *Transactions* of the Royal Academy of Science, Amsterdam, Holland, on the metastability of other metals.

The importance of the subject may well be judged from Professor Cohen's statement: "Physical constants of metals, as they are given to us for the present, have to be considered as chance values, which are a function of the past thermal history of the material experimented upon." (*Zeitschrift für Physikalische Chemie*, 1915). All of us who have to do with physical constants are fully aware nowadays that the greater majority of figures given in the usual tables are nothing but approximations, good enough for orientation, but no more than that, and certainly they are far away from being as accurate as is suggested by the number of decimals which are usually given. Accurate recent determinations of the electric conductivity of "pure copper" of recent date, range from 62 to 65.2, so we should be very cautious when trusting on figures for properties.

To Cohen we are obliged for the explanation *why* it is that there is such a diversity in the figures for physical constants; indeed there is very little constancy in them. Cohen has conclusively shown that if a sample of a metal is chemically pure, this does not necessarily mean that it is also physically pure; that is, a 100 per cent metal *M* may be composed of *b* per cent alpha *M*, *c* per cent beta *M*, *d* per cent gamma *M*, etc.

The allotropic modifications of a metal exercise a very marked influence on its properties and for this reason a figure for some property is a chance figure, its value depending on the ratio of alpha, beta, gamma, etc., modifications in the sample. Add to this the fact that the state of molecular equilibrium is not the most frequent one in ordinary metals and that, on the contrary, all metals are as a rule in a metastable state, and it will be easily understood that the past history of a metal or alloy is of paramount importance because it determines the mutual ratio of allotropic modifications. It goes without saying that the *thermal* past history is of chief importance in this connection.

Allotropy of Cadmium[1]

Matthiesen's researches on the electric conductivity of metals (1862) are familiar to every student. In fact, notwithstanding the early date of his experiments, his figures are quoted in a great many instances, and some still accept Matthiesen's standard copper = 100, although modern copper has a conductivity higher than 100, according to this scale, and although the modern system of units should be preferred to any arbitrary scale of obsolete character. Even Matthiesen in his day noticed for cadmium a marked molecular change at a certain temperature (80 deg. C.).

Cadmium, like most metals, shows the usual inertia for change, and the retardation is so great that special precautions have to be taken to notice the change; this is probably the cause why the allotropic modifications have escaped the attention of former scientists. The change, alpha to beta cadmium occurs at 64.9 deg. C. The beta cadmium has a larger specific volume than the alpha modification; this explains Matthiesen's observation that at 80 deg. C. his sample of cadmium was so brittle as to fall to pieces.

From measurements with the pyknometer and the dilatometer, Cohen and his pupils concluded that cadmium has a transition temperature at 64.9 deg. C. and that this metal in general is a metastable system in consequence of the very strongly marked retardation which accompanies the reversible change of the allotropic modifications, both below and above their transition points.

Former experiments on copper and zinc pointed to the desirability of investigating whether or not cadmium did or did not exist in more than two allotropic modifications, and further research proved that, like copper and zinc and other metals, cadmium may exist as alpha, beta and gamma cadmium, the proportions of which depend on the past history of the sample, and this being so, the transition point 64.9 is only an apparent one. It seems probable that above 100 deg. C. the gamma cadmium is the stable form and below 50 deg. C. the alpha cadmium, so that in between 100 deg. and 50 deg. cadmium is chiefly beta cadmium.

The exact behavior of cadmium is of paramount importance for the construction of standard cells as each cadmium modification has an electrolytic potential of its own.

Ordinary cadmium has to be stabilised to the alpha form before use in a cell, if not the "standard" voltage is bound to vary, to decrease, until all the metal has been changed to alpha cadmium.

It may be well to mention here that the metastable transition point of the reaction alpha cadmium $\rightleftarrows$ gamma cadmium is 94.8 deg. C., and that if one gram-atom of alpha cadmium is transformed into gamma cadmium, the change is accompanied (at 18 deg. C.) by an absorption of 739 gram calories. Electrolytically deposited cadmium is not the stable alpha but the unstable gamma cadmium. This fact is quite in accordance with what should be expected and is of practical importance since the method of making cadmium cells is to deposit the metal electrolytically. This is another instance of the common phenomenon that it is not the stable modification of a metal that is first formed, but the stable form has to be reached via unstable forms.

The conclusions arrived at are: First, that the metal cadmium, as familiar to us is a metastable system containing more than two allotropic modifications, and, second, many of the mysterious phenomena belonging to cadmium cells can be explained when taking into consideration the above mentioned fact.

Allotropy of Lead[2]

Rather large discrepancies in the physical constants given for lead indicate that here again we have to do with a metal in more than one modification.

The density of purest lead (Kahlbaum 0.001 per cent Cu, 0.0006 Fe) taken as 11.324, increases to 11.341 after treatment at 15 deg. C., it decreases again to

[1]Communications, Oct., 1913; May, 1914; Oct., 1914; Jan., 1915.

[2]Communications of Nov., 1914; Jan., 1915.

11.313 after treatment at 50 deg. C., and it increases again to 11.328 after treatment at 25 deg. C.

The experiments have not yet been concluded, but from what could be observed it is evident that lead, as it has been known up to the present, forms a metastable system containing simultaneously several allotropic modifications of this metal.

The well known form of lead as a lead-tree is one of the metastable modifications.

Allotropy of Zinc[3]

Scientists seem to have recognized as early as a century ago that zinc is not always the same substance. Practical men have known as long as they have used zinc that one of its peculiarities is that in summer time it expands, but after return to average temperature it does not return to its original dimensions.

In a cold winter zinc contracts but never again resumes exactly the original length, and everyone familiar with zinc roofing knows that zinc should never be cut lengthwise, but always crosswise, though the greater length lengthwise would encourage one to do otherwise if he has to make long strips for tubing or other building purposes.

Practical men know that new zinc possesses that property of not resuming again its original length in a much greater degree than old zinc. Real trouble may result from neglecting the fact that zinc, and more especially sheet zinc, is a metal not to be trusted as regards its length. In case we have circular discs, as is often the case with instruments, warping is the effect of said unequal behavior lengthwise and crosswise the direction of rolling.

The researches of Cohen have not elucidated the strange phenomena. They are strange unless they also can be attributed to metastability at ordinary temperatures.

Practical men also know that zinc cannot be rolled unless heated to a temperature of about 120 deg. C., and they also know that zinc can very easily be pulverized when heated to about 200 deg. C. Cohen did find that prolonged heating to 25 deg. C. had a very marked influence on the density of the zinc. A considerable contraction occurred. Further data are promised by Cohen.

For another transition point, temperatures of 350 deg., 321 deg., 330 deg. 300 deg. are given by different authors, also 170 deg., so that for the present it is best to wait until Cohen and his collaborators will have finished their determinations.

Allotropy of Sodium

The change from alpha sodium to beta sodium does not occur, but beta sodium changes to alpha at a temperature of about 95 deg. C. The transformation of sodium evidently is a case of monotropy that means that the change of one modification into the other is not reversible, it goes one way only. For the present this fact is hardly of any technical importance.

The lesson to be learned from these results is that all numerical data bearing on physical constants have to be revised or checked. No figures should be trusted, and experiments should be carried out on pure metals in their stabilized form. Physical "impurities" in the form of allotropic modifications influence the properties quite as strongly as chemical impurities.

The **Explosibility of Acetylene** is the title of technical paper 112 of the Bureau of Mines. Results of experiments on acetylene—air mixtures and their relation to mining are given. The authors are G. A. Burrell and G. G. Oberfell.

[3]Communicated Nov., 1913; May, 1914; Oct., 1914.

Thermal Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

(*Concluded from page* 910)

The Thermal Effect of Loss of Fuel By Solution

This is a subject which has been little understood, although as early as 1879 Gruner stated that the condition of ideal working required the fuel burnt by the blast at the tuyeres to be a maximum and that dissolved by the oxygen of the charge a minimum.

Prof. J. W. Richards in a brief paper before the International Congress at Düsseldorf in 1910 has attempted to refute this theorem in regard to furnaces requiring little hearth heat such as charcoal furnaces working on rich ores and therefore producing little slag. In this case Professor Richards claims that Gruner's "ideal working" would be wasteful, and greater economy is obtained by departing from it as far as possible. I am unable to accept this conclusion for two reasons. First, I have myself run a charcoal furnace on rich ores, and it is a matter of sad experience with me that when the departure from Gruner's ideal working is considerable, as shown by the small quantity of blast required to burn a pound of fuel the fuel economy is poor, and when the quantity of blast to burn a pound of fuel goes up the fuel economy increases in the same proportion, in exact accordance with Gruner's theorem. Second, Professor Richards' conclusions are contrary both to the double thermal equation, which I have outlined above, and to the old-style heat balance, even for conditions entirely outside those of present practice.

TWOFOLD FUNCTION OF THE CARBON

Just why Gruner's theorem should be true is not apparent on the surface. We naturally think that as the purpose of the blast furnace is to reduce iron ore with carbon, the sooner the carbon starts on its task the better. The reason this is not true depends fundamentally upon the fact that the carbon has to perform two functions and that its capacity for the two tasks is very different. One of its duties is to reduce the iron ore by carrying off the oxygen, the other is to supply the heat for this reaction which is highly endothermic and for the other requirements of the process which are just as important. Referring to Table III it will be seen that when carbon burns to CO_2 it develops 5470 B.t.u. per pound of O consumed, while the dissociation of iron oxide absorbs about 7500, this varying slightly with the oxide. If the carbon is burnt only to CO the conditions are much worse since in that case the heat developed per pound of oxygen is only 3280 B.t.u.; less than half as much as the removal of the same qantity of oxygen from the ore requires, so that for purely thermal reasons we must have in this case about twice as much carbon as would suffice for reduction.

From the thermal balances already given it may be seen that the total heat required is about twice as great as the reduction heat, and on this basis the surplus of carbon required for heat development over that for oxygen removal is still greater. The greater includes the less, and our problem is then one of heat development, not of oxygen removal.

Turning then to the heat developed, that per pound of carbon burnt to CO is 4375 B.t.u. and per pound burnt to CO_2 is 14,750 more than three times as much. We have already seen that the carbon necessary for heat development is two or three times as large a quantity as can be oxidized by the oxygen of the ore, therefore in order to burn it with any degree of completeness we must have oxygen from some other source. This source must obviously be the blast. We have seen that the heat developed for one unit of oxygen per unit

of carbon (producing CO) is less than one-third of the heat developed for two units of oxygen per unit of carbon (producing CO_2).

Turning this statement around we may say that the second unit of oxygen develops over one-half more heat than the first or that the rate of heat development after consuming the first unit of oxygen is much more rapid, in proportion to the oxygen used, than the rate up to that point. In other words, the more oxygen we deliver to carbon the more heat we shall get in an increasing degree right up to the point of saturation, CO_2.

These facts are all the results of a single cause, that the addition of the first unit of oxygen to carbon results in its conversion from the solid state into the gaseous with the absorption of a large amount of latent heat of vaporization exactly as when ice is converted to water and the water to steam. The second unit of oxygen develops 10,400 B.t.u. per pound of carbon, if the first did as much the heat developed per pound of carbon burnt to CO_2 would be 20,800 B.t.u., instead of the 14,750 actually developed; the 6050 B.t.u. which disappear represents the latent heat of gasification of the carbon.

THE OXYGEN WHICH CAN BE IMPARTED TO THE CARBON IS LIMITED

Now we are strictly limited in the amount of oxygen we can impart to the fuel in the hearth by the fact that CO_2 cannot exist at all in the presence of incandescent carbon, therefore if we burn *all* the carbon of the fuel to CO at the tuyeres we have reached the limit, and any carbon which is dissolved in the upper part of the furnace and fails to reach the tuyeres deprives us of the power of imparting a corresponding amount of oxygen, which deficiency can never be made up and represents a net loss of heat development when the gas is discharged from the stock.

MINIMUM AMOUNT OF CARBON HAS SUFFICIENT OXYGEN-CARRYING POWER

In order to confirm this conclusion, let us take the case to the limiting condition. Let us suppose that CO could be oxidized entirely to CO_2 by oxygen of the ore, then the heat developed per pound of carbon would be 14,750 B.t.u., and let us assume that the minimum heat requirements are 75 per cent more than the heat of reduction which for Fe_2O_3 is 3145 B.t.u. per pound of iron, so that the total requirements per pound of iron would be 5500. Then 0.373 lb. of carbon would be required per pound of iron, and if this were all burnt to CO at the tuyeres (Gruner's ideal working) it would take up $0.373 \times 4 \div 3 = 0.497$ lb. of oxygen there and would require as much more from the ore to saturate it, producing all CO_2 at the top of the furnace. The oxygen per lb. of pig iron in Fe_2O_3 is $0.95 \times 0.428 = 0.406$ lb., which would convert the CO formed at the tuyeres to 82 per cent CO_2 and 18 CO, about the equilibrium ratio for 900 deg. as we have already seen. In other words, the theoretical minimum of carbon would have oxygen-carrying power sufficient to reduce the ore completely, and if any of the possible oxygen be lost by the failure of a part of the carbon to reach the hearth and take up its share there, the total supply would be insufficient for the oxidation of the carbon to this equilibrium ratio.

COMPARATIVE RESULTS WITH VARYING SOLUTION LOSS

In order to show the facts in regard to this question graphically I have made an analysis of it by taking the solution loss as the independent variable which brings out some facts that are the exact opposite of generally accepted opinion.

For simplicity I have assumed that the iron produced contains no manganese and phosphorus and that the silicon is 1.5 per cent, this assumption gives results practically identical with those which would result from the use of the actual percentages of these three metalloids in ordinary steel-making irons.

Let us assume as the basic case a furnace working with a slag volume of 50 per cent and making a ton of iron containing 1½ per cent Si with a ton of coke (2240 lb.) and blown in four different cases with 50, 55, 60 and 65 cu. ft. of actual air at 70 deg. Fahr. Let us assume that the coke contains 2000 lb. of fixed C and that 80 lb. of this are required for carbonizing the iron, leaving 1920 lb. for combustion. Let us disregard the work done in the hearth altogether and consider the materials which descend to the hearth as discharged from the shaft in the solid condition at the top of the bosh. We have already seen that such a calculation is possible in spite of our complete ignorance of the temperatures at which the gases in the charge are driven off and consequently of how much heat it required to raise them to this unknown temperature. We charge against the total heat received plus that developed in the shaft, the heat required for the chemical reactions of the shaft and that discharged from the bottom of the shaft and by radiation, the balance is then credited to the top gases, and from it we can readily figure the temperature of the latter. The temperatures found by this method in the different cases will evidently give us a measure of the effect of solution loss in the shaft of the furnace.

EFFECT OF SOLUTION LOSS ON HEARTH HEAT

The effect of solution loss on hearth heat is simple, almost obvious. The chart, Fig. 1, gives hearth heats developed not per pound of coke charged, but per pound of coke burnt in the hearth, with oxygen from the blast. Obviously any coke which does not reach the hearth can furnish no such heat at all, and it is further obvious on reflection that oxygen from other sources than the blast even set free in the hearth does not count in the development of hearth heat because any such oxygen involves the dissociation of other compounds, FeO, SiO_2 and the like, and there is not enough heat developed by the combustion of such oxygen with carbon to keep the reaction going without additional heat from some other source. So of course there is none available above the critical temperature, therefore no hearth heat developed at all.

Obviously then the hearth heat developed per pound of fuel is directly proportional to the cubic feet of blast required to burn that fuel, other things being the same, that is, the more blast we blow per pound of coke the more hearth heat per pound of coke we develop in exactly the same proportion.

In making the calculation, I have assumed that the blast was dry since this saves much complication in regard to the shaft heat calculations, and the comparative results are not affected at all thereby.

Now our calculation in detail becomes as follows:

CASE 1.—1920 lb. of carbon for combustion (by blast and ore together) equals 0.857 lb. per pound iron; 50 cu. ft. of blast at 75 lb. per 1000 cu. ft. equals 3.75 lb. and 23 per cent of this gives 0.864 lb. O. Assume the ore to be Fe_2O_3 and the iron to contain 95 per cent Fe and we obtain 0.407 lb. of O per lb. iron from this source.

0.015 lb. Si carries with it 0.017 lb. O, and assuming that 0.1 lb. of H_2O is decomposed in the shaft which is about in accordance with Mathesius' and Cornell's figures we obtain 0.089 lb. O from this source. Then the total O per pound of iron is as follows:

From blast (dry)	0.864
From SiO_2 reduced	0.017
From Fe_2O_3	0.407
From H_2O decomposed in shaft	0.089
Total O =	1.377
O required for .857 C to CO = .857 × 16/12 =	1.143
O left for CO to CO_2 = 1.377 − 1.143	0.234
Carbon to CO = (1.143 − .234) × ¾ =	0.681 lb.
Carbon to CO_2 = 0.234 × ¾ =	0.175 lb.

Assuming that 10 per cent of the oxygen of the ore is removed by solid carbon in the hearth in accordance with our previous conclusion we have the oxygen in the hearth as follows:

From blast	0.864 lb.
From SiO_2	0.017
From 10 per cent of O in ore	0.041
	0.922

The carbon consumed in the hearth is therefore 0.922 × ¾ = 0.691 lb.

The CO resulting from the combustion of this is 0.691 × 29.85 = 20.6 cu. ft.

The nitrogen of the blast is .79 × 3 × 50 × 492 ÷ 530 = 36.9, add 20.6 cu. ft. CO and we have 57.5 cu. ft., total gas coming in from hearth.

The sensible heat of this gas at 2750 deg. = 58.8 B.t.u. per cubic foot.

Heat brought into shaft by gas from hearth 57.5 × 58.8 = 3380 B.t.u.

Of the 0.857 lb. carbon charged there is consumed in the hearth 0.691 lb. leaving 0.166 lb. to be consumed in the shaft by oxygen from the ore.

This requires 0.166 × 1.33 = 0.222 lb. oxygen. The ore contains 0.4070, but 10 per cent is not available in the shaft, so all we have available is 0.407 × 0.90 = 0.366 lb., deducting 0.222 lb. from this we have left 0.1440 O from the ore to which we add 0.1 × 8 ÷ 9 = 0.089 lb., the oxygen from the water dissociated in the shaft, making 0.233 lb. O for converting CO to CO_2.

This checks with the total oxygen calculation given before, which is much simpler but does not separate the C into the two portions that burnt to CO and that to CO_2 in the shaft. We can now figure the heat developed in the shaft very simply.

0.166 lb. C burnt to CO develops .166 × 4375 =	727	B.t.u.
0.233 × ¾ C as CO burnt to CO_2 develops 0.175 × 10,400 =	1820	
Add to this the heat brought in from the hearth	3380	
Total heat for operations in the shaft	5927	B.t.u.
To reduce 0.9 of ore, the heat consumed is	2670	B.t.u.
To decompose ½ lb. stone	405	
To heat slag forming materials (½ lb.) to 2750° F.	300	
To heat iron (1 lb.) to 2750° F.	480	
To heat carbon in iron	45	
To evaporate 0.25 lb. H_2O to steam	280	
To decompose 0.1 lb. H_2O from steam	580	
	4760	B.t.u.

On the basis of our assumption that the water evaporated decomposed is a certain percentage of the weight of the iron these items all depend upon the weight of iron produced and vary with it, when we assume the weight of iron produced per pound of coke to vary as we presently shall.

In addition we have radiation which, on the basis of our previous data is 440 B.t.u. per pound of iron under these conditions but is constant and does not increase with the iron per pound of coke, and the heat required to bring up to the critical temperature the coke that goes down out of the shaft into the hearth which, of course, changes with the weight of coke consumed in the hearth.

In this case it is 0.691 C × total heat of coke, 1159 B.t.u. = 800 B.t.u.

Adding these items we have as the total heat required in the shaft

Constant heat required for pound of iron as above	4760
Required for heating coke	800
Required for radiation	440
	6000
Total heat for operation in shaft	5927
Balance (B.t.u.)	−73

This is 73 B.t.u. *more* than the heat developed in the shaft, but let us ignore this fact for the present and say that it merely corresponds to the fact that furnaces never run with so small an amount of blast as 50 cu. ft. per pound of coke, in other words solution loss is never so bad as we have assumed. Presently we shall see that this is not necessarily true, but we will not consider that now, merely assuming for the present that this represents the impossible case.

To compute the temperature of the top gases we can figure their volume and take their specific heat per cubic foot as 0.02 since this is extremely close and the error introduced by that assumption is not important enough to justify an accurate calculation of this factor.

The total carbon from the coke is 0.857 lb. or 0.857 × 29.85 =	25.6 cu. ft.
Nitrogen as above	36.9 cu. ft.
CO_2 from ½ lb. of stone (12 per cent C) = 0.06 × 29.85 =	1.8 cu. ft.
H_2 from 0.1 lb. H_2O = 0.1 × 1/9 × 178 =	2.0 cu. ft.
	66.3

The specific heat of this at 0.02 B.t.u. per cubic foot is 1.33, hence we get −73 B.t.u. ÷ 1.33 = −55 deg. Fahr.

This temperature is normally measured from 32 deg. Fahr., but if we do that we should take account of the heat of the materials charged and it is simpler to reckon the temperature of the top gas from that of the raw materials which makes no appreciable error. Taking this temperature at 60 deg. we have the top gas passing off in this case at 60 − 55 deg. = + 5 deg. Fahr.

The gas analysis in this case is as follows:

CO_2 from combustion 0.175 × 29.85 =	5.3 cu. ft.	
CO_2 from stone as above	1.8 cu. ft.	
	Cu. Ft.	Per Cent
Total CO_2	7.1	10.7
CO from combustion of 0.857 − 0.175 = 0.682C 0.682 × 29.85 =	20.3	30.66
Nitrogen as above	36.9	55.6
Hydrogen from dissociation of H_2O as above	2.0	3.1
	66.3	100.0

Case 2.—We now assume that the solution loss is less, so that 55 cu. ft. of blast at 70 deg., 10 per cent more than in the previous case, are required to burn a pound of coke, other conditions remaining as before.

The oxygen in the blast now becomes 0.864 × 1.1 = 0.95, and the other sources of oxygen remaining the same, the total becomes 0.017 + 0.089 + 0.407 + 0.95 = 1.463, and the oxygen to burn all the coke to CO remaining as before 1.143 lb., the oxygen available for CO to CO_2 is 1.463 − 1.143 = 0.32 lb., which burns 0.24 lb. C to CO.

The coke burnt in the hearth is ¾ (0.95 + 0.017 + 0.041) = ¾ × 1.008 = 0.756 lb.		
CO formed by this is 0.756 × 29.85 =	22.6	cu. ft.
The nitrogen is 36.9 × 1.1 =	40.6	
Total gas coming in from hearth =	63.2	cu. ft.
Heat brought in by this at 2750 deg. = 63.2 × 58.8 =	3710	
C burnt to CO in shaft = 0.857 − 0.756 = 0.101		
Heat produced by this 0.101 × 4375 =	438	
C as CO burnt to CO_2 in shaft as above 0.32 × ¾ = 0.24 lb.		
Heat produced by this 0.24 × 10,400 =	2495	
Total heat available in shaft =	6643	
Heat required per lb. of iron as before	4760	
To bring coke burnt in hearth to 2750 deg. = 0.756 × 1159 =	877	
For radiation =	440	
Total heat available for shaft	6077	
	6643	
Surplus for gas = 6643 − 6077 =	566	B.t.u.
Gas volume is as before except the nitrogen is increased 10 per cent = 3.7 cu. ft., 66.3 + 3.7 =	70	cu. ft.
Heat required to raise gas 1 deg. at 0.02 B.t.u. per cu. ft. sp. ht. of gas = 70 × 0.02	1.4	

566 ÷ 1.4 = 404 deg. + 60 deg. = 464 deg. discharge temperature of the gas.

The gas analysis in this case is as follows:

Total carbon gas from fuel as before is 25.6 cu. ft., the $CO_2 = 0.24 \times 29.85 = 7.26$ cu. ft. and the CO is 18.4. The carbon dioxide from the limestone is 1.8 which added to 7.2 gives 9 cu. ft., the H_2 as before is 2 cu ft. and the nitrogen is $36.9 \times 1.1 = 40.6$.

Then the percentages are

CO_2	9. ÷0.70 =	12.8
CO	18.4 ÷0.70 =	26.3
H_2	2. ÷0.70 =	2.9
N	40.6 ÷0.70 =	58.

CASE 2A.—Now let us assume that since the hearth heat as already shown is increased in proportion to the blast per pound of coke we increase the burden of ore and stone by 10 per cent also. The oxygen from the blast is 0.95 lb. and that from other sources is increased 10 per cent so becomes

From SiO_2	0.019 lb
From ore	0.448
From H_2O	0.097
	0.564 lb.

which added to 0.95 gives 1.514 lb. total. Deducting from this the oxygen for 0.857 C to CO, 1.143 lb. we have left 0.371 lb. O for CO_2, which suffices to burn 0.278 C as CO to CO_2.

The oxygen available in the hearth is $0.95 + 0.019 + 0.045 = 1.014$, which burns $1.014 \times \frac{3}{4}$ C = 0.76 C, leaving 0.857 — 0.76 = 0.097 lb. C to be burnt to CO in shaft.

0.097 C to CO produces $0.097 \times 4375 =$		424 B.t.u
0.278 C as CO to CO_2 gives $0.278 \times 10{,}400 =$		2895 B.t.u.
CO from hearth $0.76 \times 29.85 =$	22.7	
N from hearth as before	40.6	
	63.3	
Heat carried from hearth to shaft by gas $63.3 \times 58.8 =$		3720
Total heat for shaft =		7039
Heat required.		
For iron, etc., as before $\times 1.1 = 4760 \times 1.1 =$		5236
For heating coke 0.76×1159		881
For radiation		440
Total		6557

Excess available for heating gas 7039 — 6557 = 482 B.t.u. The volume of gas and its analysis are as follows:

Total carbon gas from fuel as before	25.6 cu. ft.		
Carbon as CO_2 from fuel $0.278 \times 29.85 =$	8.3 cu. ft.		
CO by difference	17.3 cu. ft.	24.6 per cent	
CO_2 from stone 2 cu. ft.			
Total $CO_2 = 2. + 8.3 =$	10.3 "	14.7 "	
$H_2 = 2 \times 1.1 =$	2.2 "	3.1 "	
N =	40.6 "	57.6 "	
	70.4 cu. ft.	100.0 per cent	

The specific heat of this at 0.02 is 1.41 and the discharge temperature of the gas is 482 ÷ 1.41 = 340, which added to 60, gives 400 deg.

CASE 3.—Solution loss is so much decreased that 60 cu. ft. of blast are required per pound of coke, other conditions being as in Case 1.

Oxygen in blast is $0.864 \times 1.20 =$			1.037
Other oxygen as in case I $0.017 + 0.407 + 0.089 =$			0.513
Total oxygen $1.037 + 0.513 =$			1.55 lb.
Oxygen for 0.857 C to CO as before			1.143
Oxygen for CO to CO_2			0.407
C as CO to $CO_2 = 0.407 \times \frac{3}{4} =$			0.305 lb
Oxygen in hearth $0.017 + 0.041$, (as in Case I), $+1{,}037 =$			1.095 lb.
Carbon burnt with this			0.823 lb.
Carbon left to be burnt to CO in shaft $0.857 - 0.823 =$			0.034 lb.
Heat developed by this $0.034 \times 4375 =$			119
Heat developed CO to CO_2 $0.305 \times 10{,}400 =$			3171
Volume of CO from hearth $823 \times 29.85 =$	24.6 cu. ft.		
Volume of U from hearth $36.9 \times 1.2 =$	14.3 cu. ft.		
Total volume of gas from hearth	68.9 cu. ft.		
Heat brought in by this $68.9 \times 58.8 =$			4050
Total heat for shaft			7370
Heat required			
For iron, etc., as in Case I			4760
For heating coke $823 \times 1159 =$			955
For radiation			440
Total heat required in shaft			6155
Heat available for gas $7370 - 6155 =$			1215 B.t.u.

Volume and composition of gas.

Total carbon gas from fuel as before	25.6	
CO from fuel $0.305 \times 29.85 =$	9.1 cu. ft	
CO_2 from fuel 25.6 — 9.1 =	16.5 cu. ft.	22.5 per cent
CO_2 from stone 1.8		
Total CO_2 1.8 + 9.1	10.9	14.8 "
H_2 as in Case I	2.	2.7 "
N_2	44.3	60 "
Total	73.7	100.0 "

Specific heat of this at 0.02 per cubic foot = 1.47.

Temperature of top gas = 1215 ÷ 1.47 = 826 + 60 = 886 deg. C.

CASE 3A.—Blast as in Case 3 and burden increased in same proportion, 20 per cent.

Oxygen from blast 1.037, other oxygen as in Case I, $\times 1.2 = (0.017 + 0.407 + 0.089) \times 1.2 =$			0.616
			1.037
			1.653
Oxygen for 0.857 C to CO			1.143
O for CO to $CO_2 =$			0.51
C as CO to CO_2 $0.51 \times \frac{3}{4}$			0.383 lb.
O in hearth from blast			1.037 lb.
From other sources as in Case I, $\times 1.2 = 0.058 \times 1.2 =$			0.070 lb.
Total O in hearth			1.107
This burns 0.832 C to CO and leaves $(0.857 - 0.832) = 0.025$ C to burn to CO in shaft.			
Heat from this $0.025 \times 4375 =$			110 B.t.u.
Heat from 0.383 C as CO to $CO_2 = 0.383 \times 10{,}400 =$			3980 B.t.u.
CO from hearth $= 0.832 \times 29.85 =$	24.8		
N_2, as in Case 3	44.3		
Total gas from hearth to shaft	69.1		
Heat brought in by this 69.1×58.8			4060
Total heat available in shaft			8150
Heat requirements.			
For 1 lb. iron as in Case I, $4760 \times 1.2 =$			5710
For heating coke 0.832 lb. $\times 1159 =$			965
For radiation			440
			7115
Heat available for gas $8150 - 7115 =$			1035 B.t.u.
Total volume of gas:			
Carbon gas from fuel	25.6		
CO_2 $0.382 \times 29.85 =$	11.4		
CO $25.6 - 11.4 =$	14.2 cu. ft.	19 per cent	
CO_2 from flux $1.8 \times 1.2 = 2.2$			
Total CO_2 $11.4 + 2.2 =$	13.6 cu. ft.	18.3 per cent	
$H_2 = 2. \times 1.2 =$	2.4 cu. ft.	3.2 per cent	
$N_2 =$	44.3 cu. ft.	59.5 per cent	
	74.5	100.0	

Specific heat of this at 0.02 = 1.49.

Temperature of gas 1035 ÷ 1.49 = 0.695 + 60 = 755 deg. F.

CASE 4.—Solution loss reduced to zero so that 65 cu. ft. of blast are required to burn a pound of coke, other conditions as in Case 1.

Oxygen in blast $0.864 \times 1.3 =$		1.123	
Other oxygen, as in Case I, $0.017 + 0.407 + 0.089 =$		0.513	
Total oxygen		1.636	
Oxygen for 0.857 C to CO		1.143	
Oxygen left for CO to CO_2		0.493	
C as CO burnt to CO_2 with this =		0.37	
Heat developed in shaft by this $0.37 \times 10{,}400 =$			3850
No heat by oxidation of C to CO in shaft			
Vol. of CO from hearth $0.857 \times 29.85 =$	25.60		
Vol. of N from hearth $36.9 \times 1.3 =$	48.0		
Total gas from hearth to shaft	73.6		
Heat brought in from hearth by this 73.6×58.8			4330
Total heat available in shaft			8180
Heat requirements			
For iron, etc., as in Case I			4760
Heating coke $0.857 \times 1159 =$			995
Radiation			440
			6195
Heat available for gas $8180 - 6195 =$			1985 B.t.u.
Total gas volume.			
Carbon gas =	26.5 cu. ft.		
CO $0.37 \times 29.85 =$	11.1 cu. ft.		
CO	15.1 cu. ft.	19.7 per cent	
CO_2 from stone 1.8			
Total CO_2 $1.8 + 11.1 =$	12.9	16.4 per cent	
$H_2 =$	2.	2.6 per cent	
$N_2 =$	48.	61.3 per cent	
	78.3	100.0	

Specific heat of this at 0.02 = 1.566.

Temperature of top gas 1985 ÷ 1.566 = 1266 deg. + 60 = 1326 deg.

Case 4A.—Same as last except burden increased in same proportion as blast to burn a pound of coke, 30 per cent.

Oxygen from blast	1.123		
Other oxygen, as in Case I, $\times 1.3 =$	0.666		
Total oxygen	1.789		
Oxygen for 0.857 C to CO	1.143		
Oxygen for CO to CO_2 in shaft =	0.646		
C as CO burnt to CO_2 with this	.485 lb.		
Heat developed by this $485 \times 10{,}400$		5040	
No heat from oxidation of C to CO in shaft			
Gas from hearth to shaft as before 73.6			
Heat brought in by this as before		4330	
Total heat available in shaft		9370	
Heat requirements:			
For iron, etc., as in Case I, $\times 1.3 = 4760 \times 1.3 =$		6190	
Heating 0.857 coke as before		995	
Radiation		440	
Total		7625	B.t.u.
Available for gas heating $9370 - 7625 =$		1745	B.t.u.
Total gas volume:			
Carbon gas from fuel	25.6 cu. ft.		
CO_2 $0.485 \times 29.85 =$	14.5 cu. ft.		
CO	11.1 cu. ft.	14.2	per cent
CO_2 in stone $1.8 \times 1.3 = 2.3$			
Total CO_2 $2.3 + 14.5 =$	16.8 cu. ft.	21.4	per cent
$H_2 = 2 \times 1.3$	2.6 cu. ft.	3.3	per cent
N_2, as in Case 4	48.0 cu. ft.	61.1	percent
	78.5	100.0	

Specific heat of this at 0.02 per cu. ft. = 1.570.

Temperature top gas = $1745 \div 1.57 = 1110$ deg. + 60 = 1170 deg. F.

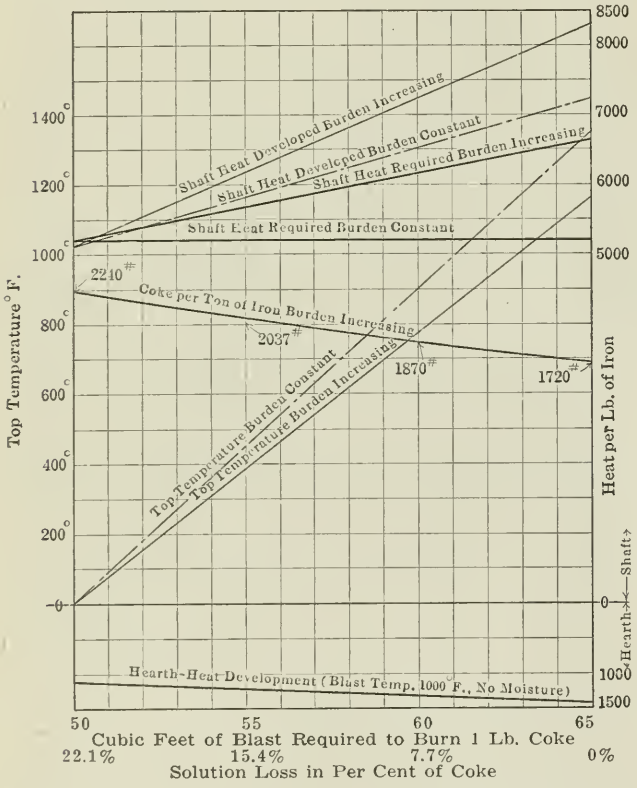


FIG. 3—THE EFFECT OF SOLUTION LOSS ON HEAT DEVELOPMENT AND TOP-TEMPERATURE WITH BURDEN CONSTANT AND WITH BURDEN INCREASING AS SOLUTION LOSS DECREASES

Fig. 3 shows these results graphically. Above the zero line we have the heat developed and that required in each of the four cases and the three sub-cases but in order to have the total correct the heat required to bring the coke up to the critical temperature is deducted from both sides alike. This is perfectly correct, for we could, if we liked, have deducted from the heat brought in by the gases rising from the hearth, the heat required to heat the coke to the critical temperature, and counted the balance as that available for heating the rest of the charge and the gas. We have in fact virtually done this by adding the heat for the coke to the requirement side instead of subtracting it directly from the heat available side. If we left this in on both sides we should be counting the heat required for the coke twice and should not get a correct total by adding the hearth heat to the above quantities.

We can readily plot the hearth heat below the zero line and the total distance between this and the lines of shaft heat requirements gives the total requirements for the given case. We may obviously assume for case 1 representing 1 lb. of iron that the hearth heat developed is 1100 B.t.u. in accordance with the actual data of operation given above. This is derived by the combustion of that coke which is burnt with the oxygen of the blast or $\frac{3}{4} \times 0.864 = 0.648$ lb. C.

Our diagram of hearth heat is based on 0.85 lb. C burnt with blast and 1100 B.t.u. for 0.648 lb. C corresponds to 1440 B.t.u. per 0.85 lb.; assuming 0.5 lb. moisture per 1000 cu. ft. of blast we find that 1000 deg. blast temperature produces the required amount of hearth heat. Assuming these conditions to remain the same, the hearth heat increases in proportion to the blast per pound of coke as explained above, and starting at 1100 B.t.u. in case 1 it rises to 1430 B.t.u. in cases 4 and 4A.

Let me reiterate here that these calculations show what the thermal condition *would be*, if we could have the amount of solution loss assumed in each case, without asserting that this is possible. We can now proceed to interpret these results.

Analysis of Results

HIGH SOLUTION THE LEFT SIDE OF THE DIAGRAM

Let us return now to the impossible top temperature in Case 1, 55 deg. below the temperature of the entering charge which might seem to indicate that a furnace could not operate under conditions even approximating these.

As a matter of fact furnaces can and do operate under conditions very similar to these and strange as it may seem they do it by increasing the blast temperature. Since the blast constitutes about 80 per cent of the gas, an increase of 200 deg. blast temperature will give an increase of about 160 deg. top temperature and so raise the temperature of the top gas to 165 deg. which is still below the top temperature at which furnaces run. But referring to the diagram we find that for 51.25 cu. ft. of blast the top temperature rises to 100 deg. and adding the 160 deg. for a higher blast temperature we obtain 260 deg. for these conditions, which correspond very closely in all important particulars to those under which many furnaces operate when using much Mesabi ore. It is necessary to emphasize the fact that in such a case more heat is developed in the hearth than is needed there, and that the excess passes up into the shaft and does work there which should have been done by heat of lower temperature under more correct conditions of working. This would leave this hearth heat to be utilized for the final smelting of a larger burden.

This is precisely the condition described before, under which the charcoal furnace was working on wet ore.

The chart shows quite plainly that only about one-fifth to one-fourth as much hearth heat per pound of fuel is generated as of shaft heat, so it is obviously a waste of fuel to employ this hearth heat for use in the shaft just as it would be to employ water from hydraulic pumps under 1200 lb. pressure to feed boilers under 200 lb.

This is in accordance with the general law of thermodynamics that any application of heat at a temperature lower than that at which it is developed results in an increase of entropy and a decrease of availability.

Obviously this corresponds to the case of Cornell as against that of Mathesius. In the latter's case only 1000 B.t.u. of shaft heat were developed per pound of iron, in the former's case 1250 B.t.u., because it was doing work in the hearth that should have been in the shaft and this surplus of high-temperature hearth heat was being largely wasted on low-temperature operations. Probably this was due to incorrect filling or a scaffold causing irregular descent of the charge into the hearth since if it were due to excessive solution loss there would be a deficient development of heat in the shaft whereas there is really an excess so far as our figures give reliable indications.

LOW SOLUTION LOSS THE RIGHT-HAND SIDE OF THE DIAGRAM

Passing now to the other side of the diagram, cases 4 and 4A, the oxygen from 65 cu. ft. of blast plus that from the silicon is exactly enough to burn all the coke without leaving any for the 10 per cent of oxygen from the ore which we have already seen is only removed in the hearth and we may therefore safely admit that this case is beyond the limit of present possibility.

From the detailed calculation it appears that 62 cu. ft. of blast is about the maximum that still leaves carbon enough for the removal of the last 10 per cent of oxygen in the ore and a vertical line in the diagram through this quantity of blast indicates approximately the practical limit in this direction of the amount of blast per pound of coke that can be blown for these conditions, but, of course, if the quantity of fixed carbon in the coke were greater than that assumed as the basis of the calculation, then the theoretical maximum limit of blast per pound of coke would be proportionately raised.

We find in this the probable explanation for the excess hearth heat in the case of Reece, for in my first work on this subject (see the report quoted before) I did not realize that at least 10 per cent of the oxygen of the ore was necessarily removed in the hearth, and since my figures for blast volume based on piston displacement indicated that enough blast was blown to burn all the coke I assumed this to be the case; but these figures for blast volume depend on several allowances and the results are not absolutely positive. They must, therefore, give way to the small extent required by the later deduction founded on more accurate data; that 10 per cent of the oxygen of the ore is removed by direct carbon in the hearth with a corresponding loss of carbon.

The minimum loss is represented by the difference between 65 cu. ft. and 62 cu. ft. of blast per pound of coke or 5 per cent, but as a matter of fact the solution loss is probably never less than 10 per cent and a deduction of 10 per cent from the hearth heat in Reece's case, 1170 B.t.u., would bring it down to 1053 B.t.u., virtually identical with that of Mathesius. This reduction in the amount of total oxygen would also reduce the shaft heat to a figure as close to that of Mathesius as such calculation will ever come honestly.

The better agreement, brought about by this correction, between the results of two cases varying widely in time, place, and conditions, seems to me to confirm both the correctness of the thermal calculation as a whole and the accuracy of our conclusion, as to the removal of the final fraction of the oxygen of the ore in the hearth.

I believe it will be generally admitted that these theoretical maximum and minimum limits of blast blown are in exceedingly close agreement with the facts of practice.

It will be seen that the coke consumption for this high limit of blast blown is about 1800 lb. whereas the results reported by Mathesius are considerably lower than this, 1682 lb., and the more recent work of Howland at the plant of the Wisconsin Steel Co. has produced a still lower figure, about 1640 lb.

These facts, however, do not in the least controvert our diagram, but rather confirm it, for we have assumed only 1000 deg. blast temperature, whereas these remarkable results were obtained with blast temperatures of about 1250 deg. corresponding to the production of 23 per cent more hearth heat per pound of coke burnt with blast. Sixteen hundred and forty pounds being only 8 per cent less than 1800 lb., it is obvious that enough hearth heat could be developed with about 15 per cent less coke burnt by blast than in our limiting case with 62 cu. ft. of blast; which would correspond to about 53 ft. of blast; this was in fact the precise amount used by Mathesius. Moreover the total carbon in Howland's practice is 93 per cent against 89 per cent as assumed above, while the sulphur in his coke was so low that the critical temperature was probably lowered by the use of a more siliceous slag.

CONDITIONS OF PRACTICE TO WHICH THE DIAGRAM CORRESPONDS. HEARTH HEAT

The condition represented by cases 1 to 4 in which the blast per pound of coke increases without any increase of burden may be compared with either of two conditions in practice. First, we may assume that the blast temperature falls or the humidity rises as the solution loss decreases so that while more coke is burnt in the hearth only the same amount of hearth heat is developed from it.

Second, we may assume that the weight of slag increases as the solution loss decreases and that as the hearth heat increases the heat required above the critical temperature for slag increases in the same proportion, so that left for iron and other hearth requirements is still the same. In either case no more iron could be smelted per pound of coke with low than with high solution loss, thus producing the conditions as to shaft heat which we have assumed.

The latter condition of larger slag volume and lower solution would correspond with lean lump ores, such as are used in the South as compared with the fine sandy but much richer Mesabis.

Such data as I have of cases with approximately the same full consumption in these two dissimilar cases confirm the results of the diagram absolutely, the top temperature being much higher in the case of the low solution loss.

The former case is approximately that of a furnace on old-range ores but with higher humidity and lower blast temperature, so developing less hearth heat per pound of coke but receiving more coke in the hearth on account of low solution loss and in these cases also confirm in a qualitative way the results of the diagram, the top temperatures being much higher under such conditions than in Mesabi practice on the same fuel consumption.

CONDITIONS OF PRACTICE TO WHICH THE DIAGRAM CORRESPONDS. SHAFT HEAT.

This brings our diagram into absolute agreement with practice as regards hearth heat and we may now turn to the question of shaft heat development.

The chart shows that the temperature of the top gases rises almost as fast when the burden is increased in proportion to the blast blown as it does when the burden is not increased at all. This is without any allowance for the fact that the limestone needed would be reduced in proportion to the increased iron produced because of the smaller amount of coke, ash and sulphur to be fluxed. With reasonable allowance for this factor the temperature would be almost the same

with the increased burden as without. This seems very surprising and the reason for it has an important bearing on the whole subject of thermal principles. This reason is that *the heat generated by the oxidation of CO to CO_2 with oxygen from the ore develops more shaft heat than is required for the preparation of the ore from which the oxygen comes.*

We have already seen that the reaction $Fe_2O_3 + 3CO = 2F + 3CO_2$ is slightly exothermic—7330 B.t.u. + 7650 B.t.u., but in this case it is much more than slightly so, for the CO brings with it a very large quantity of sensible heat due to the high temperature of itself and its accompanying nitrogen; these contribute far more than enough heat for all the other operations outside of reduction and the net result is that *if the solution loss stayed the same* the top temperature in any given case would drop little or not at all by the addition of more ore, *always provided that enough additional hearth heat were furnished to take care of the added burden in the hearth.* As a matter of fact the solution loss does not stay the same, because the approximate equilibrium between the concentration of CO_2, the fuel and the quantity of ore is disturbed and the increased CO_2 dissolves more coke, this solution is a highly endothermic reaction and it cools off the gas quite appreciably. Our diagram shows quite unmistakably, if the solution loss be diminished so that the coke burnt in the hearth is correspondingly increased and the burden increased in this same proportion that the top gas will become hotter and not colder. Solution loss can be affected in two principal ways, first by changing the characteristics of the coke itself by differences in coal used, method of coking, etc., and by changing the type of ore used. I have never had the opportunity to make a test of the top temperature on cokes of different solubility, but I believe it is well established that top heats on low-fuel runs were higher with old-range ores than they are to-day with large percentages of fine Mesabis producing high solution loss, on the same fuel consumption.

Of course, we do not find in actual practice the top heats shown by the diagram for low solution loss, because as the temperature tends to rise the solution loss rises also and automatically checks it.

RECAPITULATION

Let me reiterate here that this diagram is not intended to show what *does* happen under all conditions, but only to show what *would* happen if starting with given conditions we had a varying solution loss.

The exact conditions assumed are impossible at both ends of the scale as already explained, but the indications of the diagram are certainly in good agreement with the facts of practice in the region of the diagram between 51 and 60 cu. ft. of air per pound of coke. The value of the diagram comes not from any claim to arithmetical exactness, for such a claim would be ridiculous, but from the fact that, starting with the best data obtainable, results have been obtained which are at least truly comparative for the conditions and which are certainly in good agreement with the results of practice within the legitimate range of the diagram. This diagram makes it clear that solution has two effects the results of both of which are to diminish the economy of working of the furnace.

First, it prevents a portion of the coke from ever reaching the hearth and thereby reduces the production of hearth heat, directly in the same ratio.

Second, it reduces the total amount of oxygen which can be imparted to a given weight of coke and thereby diminishes in a greater degree, proportionally, the oxidation of CO to CO_2 in the shaft, which is the principal source of heat in that region, so that the development of shaft heat with increased solution loss drops more rapidly than that of hearth heat.

If we were to use some method different from any we now have in operation but nevertheless conceivable, whereby the development of hearth heat per pound of fuel could be noticeably increased we should be under the necessity of increasing the shaft heat just as much, in order to take advantage of it, since we have seen that these requirements for any given case bear a definite relation to each other. The only way we could secure this increase would be by a further oxidation of the top gases and this in turn could only be done by diminishing the solution loss below what it now is.

We seem therefore to be perfectly safe in saying that *for any condition of which we can conceive the higher the solution loss the lower the fuel economy.*

These considerations demonstrate that the oxygen of the ore instead of being a detriment to the smelting process is an asset of great value, for it alone is available to oxidize the CO formed in the hearth to CO_2, the reaction on which the shaft must depend for the major portion of its heat supply. This is a conception which has as far as I know never been advanced before and is worthy of some reflection.

It is interesting to note the possibility that the greater consumption required for magnetite than for hematite ores under similar conditions may be due to the smaller quantity of oxygen per unit of iron carried by that ore, 0.381 instead of 0.428, and the resulting deficiency of heat accompanies heat requirements per pound of oxygen transferred, greater than those of hematite so that a smaller development coincides with a larger demand. There are, of course, other conditions, the probability of a greater heat requirement in the hearth and of more oxygen to be removed by incandescent carbon in the latter region, and these may readily be the controlling factors. Nevertheless the other consideration is worthy of thought.

There are authentic cases on record in which furnaces have been working badly and apparently too cold in the hearth but not yielding to any of the customary treatments for that condition, which have responded perfectly when the burden was increased. At first sight this seems preposterous and I confess that I formerly listened to such stories with scepticism, but in the light of the above reasoning this becomes more comprehensible; if a furnace, admittedly lightly burdened, and therefore with a surplus of hearth heat passing up into the shaft, received an increase of burden the additional oxygen in the shaft would cause a development of shaft heat more than sufficient for the increased burden and would permit the surplus hearth heat to do its proper work on the additional ore with steadying and generally beneficial results. This is an exaggerated case of the general rule well known to most furnacemen that a heavily burdened furnace generally works better than a lightly burdened one, as long as regular conditions are maintained.

The diagram, Fig. 3, designed in the first place merely to show graphically the results calculated above is believed to have possibilities of wider use. It brings out, as nothing else I have found could do, the direct relationship between the heat requirements of the hearth and of the shaft under different conditions. These have a definite and practically unchanging ratio to one another, for any given set of conditions, and if an increase is to be made in the quantity of either kind of heat produced, it must be acompanied by a proportional increase in the other kind if a corresponding saving is to be made.

The original diagram is drawn to show the effect of

solution loss and that is accordingly made the independent variable. Cases 1, 2a, 3a and 4a, however, also correspond to an increase in the iron per lb. of coke proportional to the decrease in solution loss and as this now becomes the independent variable whose effect we wish to examine I have drawn a separate diagram, Fig. 4, of which abscissae represent a wide range of iron-coke ratios, from 0 to 2:1. Ordinates above and below the zero line represent hearth and shaft heat requirements as before.

The quantities of these for 1.1 lb. of iron per pound of coke (corresponding approximately to 2000 lb. of coke per ton of iron) have been taken from Fig. 3 and lines drawn through each from the zero point, OS and OH. It is evident that the ordinates of these lines for any other iron-coke ratio give the requirements of each kind of heat from each pound of fuel for those conditions (and, of course, those only).

It is evident that if the lines of heat development be outside these lines in *both* cases or coincide in one and lie outside in the other, we shall have a workable case; but if *either* line of heat development lies inside the line of corresponding requirements that case is unworkable. I have added to the diagram the line of shaft heat development BAC; the line of hearth heat development with increasing burden, of course, coincides with the line of OH of Fig. 4.

The cases represented by the portion of the line AB outside the line of requirements are workable cases, but those represented by the portion AC inside the requirement line are not workable.

There is one exception to this latter statement to cover the case already described of a surplus of hearth heat utilized to make up a deficiency of shaft heat.

This corresponds to the condition we should have if we increased the hearth heat for cases AC as shown by the dotted line DE as far below the line of hearth requirements as the shaft heat development for those cases is below the shaft requirements.

The slope of the line indicates how impossible it is to go far in this direction.

This corresponds to an equal distortion of both lines of the diagram downward relative to the zero line. The cases so represented are not economical, but are workable, but the cases represented by the distortion of the diagram *upward* corresponding to the utilization of shaft heat for hearth purposes are not workable, being contrary to the second laws both of thermodynamics and the blast furnace.

There is, of course, a possible limitation to the development of shaft heats which must never be forgotten,

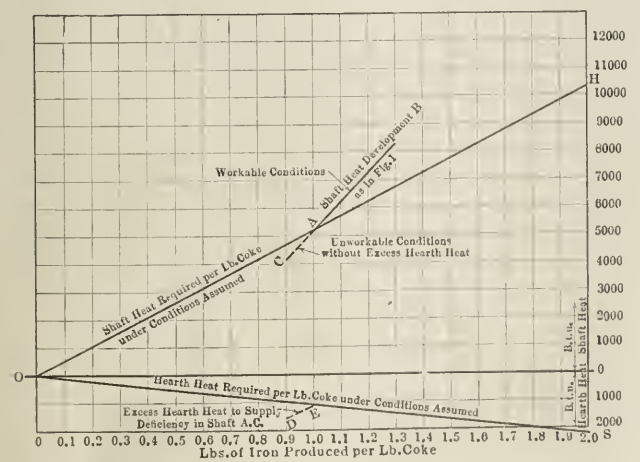


FIG. 4—DIAGRAM SHOWING HEARTH AND SHAFT HEATS REQUIRED PER POUND OF COKE UNDER NORMAL CONDITIONS FOR VARIOUS HEATS OF IRON PRODUCED

though it is further from the furthest limits of practice than we have been accustomed to think, this is the limiting concentration of CO_2 in the presence of ore, irrespective of the presence of carbon, these limits being approximately given above. We must under no circumstances draw our line of shaft heat developed per pound of fuel, beyond the limits set by this limiting ratio; to do so would be to assume that the carbon gas could be oxidized to a degree which is not possible and would lead to a fundamentally incorrect result.

There is no doubt much good work being done with quite high solution loss and some furnace men are inclined to take the stand that high solution loss is not detrimental, but in view of the foregoing demonstration of the facts I believe we are justified in saying that no matter how good work may be done under any given conditions *with* high solution loss, better could be done *without*, and the only limit to this statement comes when we reach the limiting concentration of CO_2 for the given ratio of carbon gas and ore, in the absence of fuel.

It is well to repeat that furnaces which under given conditions could not run for a deficiency of shaft heat may have this deficiency made good by an excess carried over from the hearth. I have run a furnace under such circumstances myself and know it to be true, but it is also true that it is a very uneconomical way to operate and that the hearth heat so utilized is only about one-fifth as valuable as it would be for its proper work in the hearth.

Returning now to Gruner's theorem, remembering that the lower the solution loss the greater the quantity of air required per pound of coke, we may express it tersely as follows: "The lower the solution loss the greater will be the enonomy of the furnace."

This is the conclusion to which our long and somewhat tiresome investigation has irresistibly led us and we can only pay a tribute of respectful admiration to Gruner for his early discovery of a most important law, whose consequences have been too much neglected. Professor Richards' criticism of it may perhaps be said to have erred in laying too much stress on oxygen-carrying power and too little on the necessity of developing heat which can only be successfully done by utilizing the oxygen-carrying power of the fuel to the maximum possible extent.

Conclusions

It may be well to recapitulate briefly the conclusions reached in this chapter:

For maximum fuel economy there are two principal laws.

First: Each pound of fuel must develop the maximum possible amount of heat.

Second: A certain irreducible proportion of this must be developed above the critical temperature, which is the free-running temperature of the slag.

To accomplish these results we must work along the following lines.

A. Impart as much total oxygen as possible to each unit of carbon before it leaves the top of the furnace.

B. Burn the largest possible proportion of the carbon charged with oxygen from the blast.

C. Heat the blast as hot as possible.

D. Remove the moisture from the blast as fully as possible.

E. Keep the free-running temperature of the slag as low as possible since a decrease in the critical temperature has a greater effect than equal increase in blast temperature.

F. Keep hearth requirements low by keeping down slag volume and avoiding excessive cooling for protective purposes.

G. Keep the actual hearth requirements the same as the theoretical by the use of a system of stock distribution which gives minimum solution loss in the shaft with sufficiently intimate contact of fuel and ore in the hearth.

H. Even following these rules, the hearth heat is generally deficient as compared with the shaft heat and, therefore, except in certain special cases, the heat consumption of the shaft can be increased within reason without much, if any, loss of efficiency by the furnace as a whole.

It has been my endeavor to present here as simply as possible the fundamentals of the thermal action of the blast furnace, but the inter-relations between chemical action and thermal action are so numerous that it is not possible to reduce the subject to short and simple unqualified statements.

In conclusion it may be well to warn those who desire to make thermal calculations for the purpose of investigating possibilities of improvement and the like, never to predict the ultimate consequence of a given charge until they have followed it all the way through to see if it involves any chemical or thermal impossibilities. For such purposes a sheet of the general form used in tables V-VII may be recommended as the outcome of days of effort to record the result of such calculations so that their chemical and thermal effects could be followed to the correct conclusions. But this form does not remove the necessity for a quantity of detailed painstaking and tiresome work, in the accomplishment of such purposes.

Faraday Society Meeting

At the annual general meeting of the Faraday Society, held on Tuesday, Oct. 19 last, at the Institution of Electrical Engineers, the following officers and members of council were elected to serve for the year 1915-16: President, Sir Robert Hadfield; vice-presidents, Prof. K. Birkeland, Bertram Blount, W. R. Bousfield, Prof. F. G. Donnan, Dr. Eugene Haanel, Prof. A. K. Huntington, Dr. T. Martin Lowry; treasurer, Dr. F. Mollwo Perkin; council, W. R. Cooper, Dr. C. H. Desch, Dr. J. A. Harker, Emil Hatschek, Cosmo Johns, Prof. Alfred W. Porter, E. H. Rayner, A. Gordon Salamon, Dr. George Senter, Cav. Magg. E. Stassano.

General Discussion on "The Transformations of Pure Iron"

The professional meeting was devoted to a general discussion on **"The Transformations of Pure Iron,"** and it was presided over by Sir Robert Hadfield, president, who introduced the subject under discussion.

The allotropic theory, while interesting and useful in invoking discussion, had broken down, and although the carbonist point of view had not explained all the difficulties met with, it had gone upon more tangible lines. It was to be hoped that Dr. Oxley's point of view would throw new light on the secrets of the hardening and the magnetization of iron. If it did, the discussion would be the starting point of quite a new line of thought that might bring together the allotropist and the carbonist, and offer them a common and correct explanation of the properties of iron.

Dr. A. E. Oxley of the University of Sheffield contributed the opening paper to the discussion.

It is now believed by many metallurgists that the A_2 transformation can be satisfactorily explained without assuming allotropic change; but the A_3 transformation is regarded as involving allotropy.

The crystalline state is one of extreme molecular association (physical aggregates), and if allotropy is determined merely by the extent of this association, substances will show within a finite temperature interval an infinite variety of allotropic forms, so that the attempts of metallurgists to show that A_3 involves allotropic change while A_2 does not, need not have been made. To get over the difficulty some metallurgists recognize two definitions of allotropy: (1) the two-phase (discontinuous) type, (2) the one-phase (continuous) type. The burden of distinguishing between (1) and (2) is here thrown on our experimental refinements, and it is not hopeful that a definite solution can be found.

Defining allotropy as a difference of atomic structure of the molecule (consistent with the oxygen to ozone transformation), a distinction can be made between it and crystalline grouping (physical aggregates). Allotropic modifications will usually have different crystalline symmetry; but it does not follow that difference of crystalline symmetry necessarily implies allotropy, for, according to Barlow and Pope, identical molecules can be close packed together in different ways. We must distinguish between the forces holding the molecules together so as to form a definite crystalline structure and those holding the atoms together within the molecule.

From a magnetic and thermal point of view it is concluded that the transition at A_3 involves a re-grouping of the molecules, similar to that which occurs in the ordinary process of crystallization, rather than a rebuilding of the internal structure of the molecule.

Mr. F. C. Thompson of Sheffield contributed a paper to the discussion in which he arrived at the following conclusions:

1. Sudden changes in the directions of one or more curves showing the relationship of the physical properties of iron to temperature, indicate with certainty the existence of α, β, γ, and δ iron with change-points at 768° C., 900° C., and 1400° C., while another slight change has been detected magnetically and dilatometrically at about 830° C.
2. The A_3 point in iron taken as typical of all the changes is shown to obey the same laws as hold for other acknowledged allotropic transformations.
3. Magnetic evidence is available that the molecule of β iron is Fe_3, of γ iron Fe_2, and of δ iron Fe.
4. A distinct mode of packing of the α, the β and the γ molecules is indicated crystallographically.
5. Thermally it may be shown that changes occurring in iron are of the same nature as those which occur in other cases of allotropy in metals, e.g. tin and cadmium, and also as in the case of the change from rhombic to monoclinic sulphur.

The author is therefore strongly of the opinion that the transformations in iron are essentially allotropic. At the same time he dissociates himself entirely from the view that to any of the allotropic forms *per se* is the hardness of hardened steel due. Some of the modifications will dissolve carbon as Fe_3C and some to all intents will not; but in this fact alone does the allotropy of iron bear on the constitution of steel. Whether iron is allotropic or not, it is to the solution of Fe_3C that the characteristic properties of hardened steels must be ascribed. The views of Arnold expressed in 1895 are essentially accepted to-day by the majority of metallographers, and the "hard β iron" to which the strength of hardened steel was due according to the allotropic school is dead.

Prof. Pierre Weiss of Paris, in a communication which was read to the meeting, referred to his recent work on the magnetization of iron at different temperatures, by which, through adopting newer values for the Curie constant, he has shown that there are at least three transformations in iron: the A_2, which has a physical character, the A_3, which presents a discontinuity in the susceptibility, and a third transformation in the β region, pointing to the existence of a β_1 iron with 12 magnetons and a β_2 iron with 10 magnetons in the atom. The latter change is intra-atomic and not—adopting Dr. Oxley's definition—allotropic.

M. H. le Chatelier of Paris, also sent a communication to the discussion, in which he deprecated giving a new definition to the word "allotropy." Two allotropic states were merely two clearly defined states of the same composition presenting discontinuity (Benedicks), but coexisting at the same temperature and pressure. Thus fusion and vaporization could be classed as allotropic transformations, and equally so could the A_3 and even the A_2 transformation in iron.

Prof. Frederick Soddy of Glasgow, in his communi-

cation, referred to the work of the Braggs on crystalline structure, which showed that the conception of a molecule has no meaning as applied to a solid, because the atoms of the solid are anchored and do not exist in freely moving groups, i. e. molecules, at all. Oxygen and ozone seem to be the only allotropes that survive gasification. There is little evidence that sulphur and phosphorus, or still less that the metals, behave in an analogous way.

Mr. J. E. STEAD of Middlesbrough, in a written communication, considered that a new definition of allotropy was called for after the work of the chemical crystallographers, and they had to consider whether the new definition was not open to criticism. Could Dr. Oxley explain in his own terms the breaking up of large crystals of iron into small ones when they are heated through the Ac_3 range? There must be a profound internal physical breaking down and rebuilding of the crystalline structure, accompanied by an absorption of heat.

Prof. THOMAS TURNER of Birmingham did not think that to regard changes in iron as more allied to change of physical state than to true allotropy interfered with the view that there are three distinct phases in solid iron, each possessing characteristic properties.

Dr. CECIL H. DESCH of Glasgow discussed the bearing of "dynamic allotropy" and allotropic change as defined in a narrower sense by Honda ("a change in a substance from one phase to another at a definite temperature") on the problem of the transformations in iron. From a purely chemical point of view γ iron and the modification into which it changes on passing through Ar_3 are distinct phases. He agreed with Dr. Stead as to the complete decrystallization at the A_3 point. Dr. Oxley's thermal comparisons were open to criticism as the latent heats of fusion were expressed in gram-calories per gram of metal, while the thermal evolutions accompanying allotropic and isomeric changes were given in gram-calories per gram-molecule. The correction considerably reduces the disproportion suggested. The heat evolution accompanying the change from gray to white tin, which is certainly allotropic, is 1133 gram-calories, which is less than the latent heat. Moreover, the evolution of heat in iron, apart from the necessary correction, was too low as given by Dr. Oxley, for it should include the whole area of the peak in the inverse rate in the derived differential curve. As corrected it would approximate to that for tin. He therefore concluded that there was no reason for removing the $\gamma \longrightarrow \alpha$ and $\gamma \longrightarrow \beta$ changes from the category of allotropic transformations.

Mr. A. MCCANCE of Glasgow laid down the condition that a definition must be independent of a theory, and Dr. Oxley's was not so. He also dealt with the modern conception of the molecule, touched on by Professor Soddy, and on the definite crystallization change in iron at the A_3 point emphasized by Dr. Stead. This was something more than mere closeness of packing.

Mr. T. G. ELLIOTT of Sheffield thought that Dr. Oxley's test of allotropy, involving the withdrawal of restraining forces, demanded a hypothetical condition in the material to be tested. Could crystals be built up of distorted molecules?

The President pointed out that a knowledge of the transformations of iron was essential for the successful production of hardened steel. He mentioned the interesting fact that many of the iron alloys at the temperature of liquid air attained a tenacity of 160 tons per square inch.

Prof. H. C. H. CARPENTER thought it preferable to say that iron existed in one phase below and in another phase above 900 deg. C. It was not certain that the molecule of iron was polyatomic. Judgment must be suspended until Professor Bragg had examined a well-formed crystal with the x-ray spectometer. He did not see how cooling through A_3 could lead from a more open to a closer packed cubic system, seeing that there was an expansion during the transformation. Finally, he exhibited slides illustrating the remarkable crystallographic changes that occurred when iron of exceptional purity was heated for some time at 915 deg. C. and then allowed to cool. Whether allotropic or not, very profound physical changes took place at the A_3 point.

Dr. J. A. HARKER expressed his surprise that so little work had been done in the determination of the thermal constants of pure iron. He outlined a possible method for the determination of the latent heat of fusion of pure iron.

The President offered to defray the cost of the work if it could be carried out at the National Physical Laboratory.

Prof. J. W. NICHOLSON thought the idea of a sort of atomic allotropy the really new thing in Dr. Oxley's conceptions. The fact was there were many varieties of allotropy, which needed subdivision into several groups. Bragg's work might be used in support of Dr. Oxley's hypothesis.

Prof. ALFRED W. PORTER could not understand how Dr. Oxley's definition could receive practical application, as the only method of removing the restraining forces from the molecules of a substance was by vaporizing it.

Dr. T. MARTIN LOWRY protested against altering Berzelius' definition of allotropy, which had been in use for seventy years. If a new definition was required it should be attached to a new word. He was content to think that different modifications of iron might be made up of the same molecules arranged in different ways, but in the case of an element, such as sulphur, this would still be allotropy. Dr. Oxley's thermal data were unconvincing. He might have selected changes, such as the inter-conversion of certain isomerides, in which the thermal changes were small.

Dr. E. K. RIDEAL referred to Partington's work on the vapor pressure of copper sulphate crystals, carried out by the method of passing dry air over the crystals. The differences between these values and those obtained by the static method might be explained by taking into consideration the space lattices of the crystals. Similar work might be done in the case of iron.

Dr. J. R. PARTINGTON pointed out that the atomicity of metals in the solid space could be determined from measurements of specific heat. Nernst found that nearly all the metals were monatomic.

Dr. H. BORNS asked Dr. Oxley why he had ignored Weiss's recent work, which proved that iron was polyatomic and that β iron differed from γ iron in atomicity.

Dr. A. E. OXLEY in reply said that Bragg's work was not necessarily opposed to his views, because Bragg himself agreed that in the case of complex molecules it was possible to draw a boundary round a certain group of atoms in a crystal and say that they belonged to a particular molecule.

The linear expansion found by Benedicks to occur in iron when it cools through the A_3 point was not opposed to a closer packing of the molecules in the direction of spontaneous magnetization.

With regard to the definition of allotropy, it was obvious that examples of the type of oxygen and ozone should not be classed with cases which could be explained by loose molecular association.

His definition of allotropy was theoretical to a large extent, but the idea could be followed by considering the case of ozone and oxygen. In the crystalline state these substances were different from each other; on removing the restraining forces by fusion or vaporization, they

were still more different from each other and were therefore allotropes.

Weiss's work on the magnetic properties of iron was no proof either of the atomicity of the different kinds of iron or of the magneton theory, as he assumed the truth of one to prove the other.

A paper on **"The Transference of Electricity by Colloidal Particles,"** by F. Powis of Leeds, was read by title.

An attempt is made to calculate the charge carried by the particles of a colloidal solution produced by sparking, (1) from a modification of Stokes's formula, (2) from the increase in conductivity on making the solution. Although the data available for the calculations are not very satisfactory, the second method gives a value much greater than the first. The author believes this is because the particles are not like the ions of an electrolyte solution, but that anions and cations are absorbed on their surface in such a way that the concentration of each gradually decreases with increasing distance from the particle, until each finally becomes equal to that in the bulk of the surrounding medium; the ions are so arranged, however, that with a negative colloid the layers nearer the particle contain an excess of anions, and those further away an excess of cations, whilst with a positive colloid this is reversed.

A paper on **"Electrolysis of Nitric Acid, Sulphuric Acid and Orthophosphoric Acid, Using a Gold Anode,"** by F. H. Jeffery, of the University Chemical Laboratory, Cambridge, was then presented.

(A) The platinum cathode was inclosed in a porous pot and the acid used for catholyte was of same concentration as that used for anolyte. Acids of various concentrations were obtained by diluting conc. nitric acid Δ 1·42 with distilled water. The experiments were performed at the temperature of the laboratory, 15° to 20° C. In all cases the soluble gold compounds formed contained the gold as complex anion; no gold was deposited on the cathode.

In an acid formed from 1 c.c. conc. HNO_3 to 1 c.c. water soluble compounds were alone formed. The gold went into solution, forming aurinitric acid, $HAu(NO_3)_4$, and an aurous compound, perhaps $HAu(NO_3)_2$, which deposited gold on being left in a closed flask. The anolyte was hydrolysed by water, giving a mixture of hydrated auric and aurous oxides such that $Au_2O/Au_2O_3 = 0{\cdot}02$. The anolyte changed in color from deep olive-green to dark yellow-brown on prolonged electrolysis, owing to changes in the ionic dissociation of the compounds.

In acids of concentration ranging from that corresponding to 1 c.c. conc. acid to 2 c.c. water to that corresponding to 1 c.c. conc. acid to 20 c.c. water there were solid products formed at the anode. These were mixtures of hydrated auric oxide and aurous oxide for the more concentrated acids and hydrated auric oxide alone for the less concentrated acids; for 1 c.c. conc. acid to 2 c.c. water, $Au_2O/Au_2O_3 = 0{\cdot}07$; for 1 c.c. conc. acid to 4 c.c. water, $Au_2O/Au_2O_3 = 0{\cdot}05$; for 1 c.c. conc. acid to 10 c.c. water, hydrated Au_2O_3 is alone formed; the same is true for 1 c.c. conc. acid to 20 c.c. water.

The current density did not appear to determine the composition of the compounds formed at the anode.

In the case of the dilute acids, such as 1 c.c. conc. acid to 10 c.c. water, undissociated ammonium nitrate diffused into the anolyte from the catholyte, and if the concentration of the ammonium salt was allowed to rise, compounds were formed at the anode which were explosive when heated; apparently complex cations containing gold were formed, giving a deposit of gold on the cathode.

In all cases the solid compounds gave a trace of nitric acid on heating, even when they had been previously stirred with water for weeks. This was probably due to the presence of a small quantity of a basic nitrate.

(B) In an acid formed from 1 c.c. conc. H_2SO_4 Δ 1·84 to 1 c.c. water soluble compounds were formed containing the gold as complex anion; finely divided gold was formed throughout the anolyte. The soluble compounds were at first green, becoming dark brown on prolonged electrolysis. No gold was deposited on the cathode except at the end of a long electrolysis, and then only in very small quantity. The anode potential remained constant throughout the electrolysis. When the anolyte was hydrolysed a solid was obtained consisting principally of hydrated auric oxide and aurous oxide, but it was impossible to free it from a trace of basic sulphate. The gold went into solution, forming both aurous and auric compounds. In an acid formed from 1 c.c. conc. H_2SO_4 to 7 c.c. water a solid was formed at the anode, which was a mixture of aurous oxide and hydrated auric oxide with a trace of basic sulphate. No free gold was formed in the anolyte.

(C) The quantity of soluble gold compound formed in the anolyte was very small, and the gold was present as anion alone. A solid was formed at the anode consisting of hydrated auric oxide and aurous oxide, but even after stirring with water for twenty-four weeks it could not be freed from a trace of some compound giving H_3PO_4, with water.

In an anolyte containing 15 per cent H_3PO_4 by weight the solid product corresponded to $Au_2O/Au_2O_3 = 0{\cdot}07$, and in one containing 20 per cent H_3PO_4 to $Au_2O/Au_2O_3 = 0{\cdot}09$.

A paper on **"Electrolysis of Concentrated Hydrochloric Acid Using a Copper Anode,"** by F. H. Jeffery, was then presented.

The platinum cathode was inclosed in a porous pot, and all experiments were performed in nitrogen or carbon dioxide.

The copper dissolved in the cuprous condition and as complex anion alone, there being no deposit of copper on the cathode. No chlorine was evolved at the anode. The anion appears to be $CuCl_3''$, and if the electrolysis was prolonged CuCl was precipitated according to the relation.

$$CuCl_3'' = CuCl + 2Cl'.$$

If a platinum cathode in dilute hydrochloric acid inclosed in a porous pot was used with an anolyte of KCl solution of concentration 30 grams KCl per 100 c.c. water, crystals of K_2CuCl_3 were obtained from the anolyte, the copper went into solution entirely in the cuprous condition, and no chlorine was evolved at the anode. No copper was deposited at the cathode. As before, cuprous chloride was precipitated after the electrolysis had proceeded for a considerable time.

"The Thermal Decomposition of Hydrogen Peroxide in Aqueous Solution" was the title of a preliminary note by William Clayton, of the Muspratt Laboratory of Physical and Electro-Chemistry of The University of Liverpool.

1. The rate of thermal decomposition of aqueous solutions of hydrogen peroxide is extremely sensitive toward extraneous organic matter in the colloidal state. Mechanical factors, such as volatility and the presence or absence of stirring, do not exercise an appreciable influence.

2. The chief factor in the decomposition has been shown to be the degree of purity of the water. Thus in tap-water the rate of decomposition is fully fifty times that in the purest specimen of water we have yet prepared.

3. In the light of these results, previous work upon the thermal decomposition of H_2O_2, especially the comprehensive research of Lemoine, must be considered as of doubtful value, as no special precautions appear to have been taken in regard to the solvent.

4. In view of the marked effect produced by the solvent it remains an open question as to whether the surface of the vessel exerts an appreciable effect or not; it is possible that effects previously attributed to the surface may have been due to slight variations in the organic-matter content of the solvent.

The **Burdett Oxygen Company**, with main office at Chicago, has opened a station at Fort Worth, Tex., this being the ninth station of this company.

A **Rennerfelt electric steel furnace** has been installed in the new plant of the Old Dominion Iron & Nail Works Co., Richmond, Va. This is the second of these furnaces to be used by this company.

The complete report of the Selby Smelter Commission, by J. A. Holmes, Edward C. Franklin and Ralph A. Gould, issued as *Bulletin* 98 of the Bureau of Mines, is one of the most interesting and valuable documents of the kind yet published. Methods of procedure in analyzing gases are given in detail, and supplemented by tabulated data and conclusions. Illustrations in color show the effect of sulphur dioxide on vegetation of various kinds. A bibliography is appended, prepared by the Chemists' Club Library, on the effect of sulphur dioxide on vegetable and animal life.

Extraction of Radium, Uranium and Vanadium from Carnotite

From an official advance notice on Bulletin 104 of the Bureau of Mines, entitled "Extraction and Recovery of Radium, Uranium and Vanadium, by **Charles L. Parsons, R. B. Moore, S. C. Lind** and **O. C. Schaefer**, we take the following interesting information:

This bulletin gives the results of the coöperative work with the National Radium Institute, which has been mining carnotite claims in the Paradox Valley and studying the concentration of low-grade ores at that point. The present bulletin, however, describes only the methods of extracting radium from carnotite ore as carried out in the plant at Denver.

The methods devised have proved highly successful. They depend essentially upon the fact that strong, hot nitric acid has a high solubility coefficient for radium and barium sulphates. This enables the carnotite ores to be treated directly with hot nitric acid, removing the values therefrom at a single operation. The method follows in brief:

The carnotite ore pulverized to 20 mesh is treated in a special earthenware leaching pot with 38 per cent nitric acid; 500 lb. of ore being used to 121 lb. of 100 per cent HNO_3. The acid is brought near to boiling by means of steam passed through a glass tube and the ore gradually stirred in. Heating is continued for 15 minutes when the acid is filtered from the ore in a stoneware filter. This is followed by a second treatment in the same leaching pot with somewhat weaker hot nitric acid, after which the whole is washed with hot water. Nearly all of the uranium, about 50 per cent of the vanadium and over 90 per cent of the radium are carried into solution by this method and separated from the bulky residues, which are then discarded. The acid solution is nearly neutralized with sodium hydroxide, barium chloride and sulphuric acid added in proper quantities and held in settling tanks with conical bottoms for three days to settle out the radium barium sulphate. The supernatant liquid is then syphoned into an excess of boiling sodium carbonate solution to separate the uranium and vanadium from iron, aluminium and calcium. The radium barium sulphate left in the tank is run on to a stoneware filter, filtered, washed and dried, the washings being also added to the sodium carbonate solution already mentioned.

The soluble sodium uranyl carbonate and the sodium vanadate are filtered from the iron calcium precipitate in filter presses and run into uranium precipitation tanks. The sodium carbonate is then nearly neutralized with nitric acid and sodium hydroxide added to complete precipitation of the uranium as sodium uranate. The filtrate containing the vanadium is carefully neutralized with nitric acid and iron sulphate added to precipitate vanadium as iron vanadate. Both the sodium uranate and the iron vanadate are separated from their solutions by means of filter presses. The filtrate from the iron vanadate consists almost wholly of a solution of sodium nitrate containing, of course, a small amount of impurity. This filtrate is evaporated, sodium nitrate recovered and used again for the manufacture of nitric acid. The radium barium sulphate, without further treatment, is reduced in large graphite crucibles by charcoal, a very efficient conversion (90 to 95 per cent) into barium radium sulphide being obtained. The sulphides are dissolved in hydrochloric acid and the residue of unchanged sulphates re-treated.

The chloride solutions are crystallized in the plant in silica-lined kettles, care being taken to keep the solutions acid with hydrochloric acid as the separation of radium from barium is much more rapid under these conditions. The concentrated chlorides carrying from 4 to 10 mgs. of radium per kilogram are taken to the laboratory, filtered from any insoluble impurities and crystallized again in strong acid solution until the bulk has been reduced to a small volume, when they are converted into bromides. This is done after first neutralizing with ammonia and precipitating with hydrogen sulphide to remove lead, which always accumulates and which is not precipitated by hydrochloric acid from strong barium chloride solutions. After removal of the lead the barium and radium are converted into carbonates by the addition of ammonium carbonate, washed and dissolved in hydrobromic acid. From this point on crystallization takes place in pure quartz dishes in solution strongly acid with hydrobromic acid.

The fractional crystallization of radium from the original chlorides to the finished product is neither tedious nor difficult but takes place rapidly when acid solutions are used and proper apparatus is available which will withstand their action. The efficiency of the process is high.

In connection with the radium plant, a nitric acid plant has been erected which produces over 5000 lb. of nitric acid per day. Owing to the recovery of sodium nitrate the cost of the nitric acid used has been very low, averaging under the present cost for nitrate slightly less than 2½ cents per pound. To Sept. 1 4774 mgs. of radium were produced in the form of sulfates and 1947.5 mgs. of element had been delivered in the form of bromide. Deliveries are continuing at the rate of 300 to 400 mgs. per month.

The cost of radium element figured on the basis of all the radium produced to Aug. 1, which includes the higher costs of the earlier operations, was $37,599 per gram of radium element. This includes the cost of ore, 20 per cent plant amortization, Bureau of Mines coöperation, and operating costs of all kinds, including repairs. The bulletin gives full details of operation, including detailed drawings of the plant and halftone illustrations of the plant and equipment. The radium produced is being used in the Howard A. Kelly Sanatorium at Baltimore and the General Memorial Hospital, New York City, for the treatment of cancer and other malignant growths. It is not for sale.

General Meeting of the German Bunsen Society for Applied Chemistry

The twenty-second general meeting of the German Bunsen Society for Applied Physical Chemistry was held in Berlin on Oct. 17 and 18, 1915. The president, Dr. **Hans Goldschmidt** of Essen-Ruhr, presided at the meeting. He pointed out in his speech of welcome that while most other societies were simply transacting business matters at their general meetings on account of the war, the Bunsen Society was continuing its work as in peaceful times. He thanked Professor Nernst, in whose institution the meeting was held, mentioned those who had fallen in the war and referred to the death of Professor Hittorf, whose noble personality he sketched in some detail. It was decided to leave the selection of the next meeting place to the executive committee. An invitation to come to Karlsruhe has already been extended.

A great variety of subjects, both practical and theoretical, were taken up in the papers presented.

Electrochemical Processes

A paper on the **"Electrolytic Preparation of Perborate"** was presented by Prof. K. **Arndt** of Charlottenburg. This paper described a process of the author, in which a borax soda solution is electrolyzed.

Sodium perborate $NaBO_3 + 4H_2O$ is a well-known oxygen bleaching agent. It was first produced by Tanatar in 1898 by combination of sodium metaborate with hydrogen peroxide. Sodium peroxide has later been used in large-scale manufacture. In 1898 a communication from Tanatar stated that he had obtained perborate by electrolysis of a concentrated borax solution. In 1910 M. A. Pouzenc obtained a French patent on the electrolytic production of perborate in a diaphragm cell, using a cooled orthoborate solution and rapidly circulating same. In repeating these experiments Polock could only obtain a very small output with strongly concentrated solutions and could not duplicate Pouzenc's results.

Professor Arndt's process consists in electrolyzing a solution made up of 45 grams borax and 120 grams sodium carbonate to a liter of water. In the laboratory he used a platinum gauze anode and a water-cooled tin-tube cathode; the latter is arranged in zig zag form on both sides of the anode, the distance between anode and cathode being 4 mm. At 20 amp. and 6 volts a temperature of 17-18 deg. C was maintained. The strong evolution of gas helped to keep the electrolyte in motion. The loss due to cathodic reduction was small. When the content of the bath in active oxygen is high enough the current is interrupted. After some time sodium perborate will crystallize out and can be removed and washed, forming a pure and stable product. The mother liquor may be again electrolyzed.

A paper on "**Aluminium Nitride**" was presented by Prof. **Paul Askenasy** of Karlsruhe. He mentioned the great interest which attached to the discovery of the reaction between an alumina-carbon mixture and nitrogen, in which aluminium nitride is formed at 1800 deg. C. Professor Askenasy recited the work of Serpek, the Badische Anilin and Soda Fabrik, Giulini Brothers, and the researches of Dr. W. Fraenkel and Prof. F. Fichter. Aluminium nitride, when treated with water or alkali is converted into ammonia and alumina, and a tremendous field awaits the successful execution of such a process. The author reports on the continued researches of Dr. Walther Fraenkel, with special reference to the effect of different kinds of carbon on the reaction velocity. The researches show that acetylene black was especially capable of helping the reaction. Next in order were charcoal and graphite. With coke the reaction proceeds more slowly. The alkali content of the charcoal accelerates the reaction. When larger additions of alkali are intentionally made, the acceleration of the speed of reaction is remarkable, especially when coke is used.

Temperature Scale and Atomic Weights

A paper on the "**Temperature Scale of the Reichsanstalt and the Standardization of Temperature Measurements,**" was presented by Geheimrat Professor **Holborn** of Berlin. This paper dealt with the use of gases in thermometry and pointed out that different results had been obtained with different gases, whereas it had been thought by Regnault that it was immaterial which gas was used. Differences exist already between hydrogen and nitrogen thermometers between 0 and 100 deg. which influence the measurements. The temperature scale was founded on hydrogen because this gave the lowest zero point. The International Commission of Weights and Measures adopted the hydrogen scale in 1887 between 0 and 100 deg. for the special purpose of calibrating international units of length and weight. It has also been used by the Physikalische Technische Reichsanstalt for thermometer testing. Attempts to use the hydrogen scale above 100 deg. have met with difficulties because the hydrogen attacked the glass container and penetrated metal containers. Nitrogen and air have been tried. The result has been a number of different scales which do not agree so that it was always necessary in the literature to state what kind of a scale was used. At the boiling point of sulphur there exists already a difference of several tenths of a degree.

In order to remedy these differences the Reichsanstalt made the proposal in 1911 to refer all results to the thermodynamic scale, the variations of which from other scales were known. A second proposal was made to make a practical scale which would be as near as possible to the thermodynamic scale and which would be determined by the already fixed points. Besides the fixed points the practical scale should be formed by the platinum thermometer in the range from 40 to 450 deg. C. (boiling point of sulphur). In this range the platinum thermometer forms a very simple scale if 0 deg., 100 deg. and the melting point of sulphur are fixed. It is not necessary to have especially very pure platinum. It is noteworthy that no serious differences occur between this scale and the old hydrogen scale. It is important, however, what value to use for the melting point of sulphur. Results vary between 444.54 and 444.56. The Reichsanstalt has adopted 444.55. Definite fixed points in the new scale are the melting points of Hg, Sn, Zn, Cd, and the boiling points of naphthelene and benzol. From the boiling point of sulphur to 1000 deg. any desired scale may be used. For higher temperatures radiation pyrometry comes in.

In the temperature range below 0 deg. C. many measurements have been made lately with hydrogen and helium thermometers and a close agreement has been found. It would be desirable to have melting points in this range because they are better standards than boiling points.

A paper on the "**Atomic Weights of Thorium and Ionium**" was presented by Prof. Otto Hönigschmid of Prag, Austria, in which the author gives the results of two determinations made in the atomic weight of thorium. On account of the isotropy of thorium and ionium and their occurrence together in uranium ores, the author concludes that thorium separated from uranium-containing minerals is a mixture of thorium and ionium and must have a lower atomic weight than ordinary thorium which has been isolated from minerals free of uranium. By a method using proportions between thorium bromide, silver bromide and silver, the value found for pure thorium from monazite sand was 232.151 $\pm$ 0.015 from 24 determinations. This value is 0.25 lower than the formerly determined international weight of thorium. A thorium preparation from St. Joachimsthal pitch blende was also treated to produce thorium oxide and examined spectroscopically. It was found to be identical chemically and spectroscopically with the purest thorium from monazite sand. The average of six determinations on the atomic weight gave 231.507 $\pm$ 0.012, which is 0.65 lower than ordinary thorium. The bromide of this thorium isolated from uranium ore appears intensively violet in the dark, similar to radium bromide and gives off strong alpha rays, differing in both these properties from common thorium bromide. The author says the differences in the atomic weights are due to the presence of ionium. The ionium content is figured as 30 per cent.

Other Papers

A paper on the "Reaction Between Ferrous Oxide and Carbon and Carbon Monoxide and Iron," by Dr.

V. Falcke, of Leipzig, dealt with the author's redetermination of the equilibrium between CO and Fe and C and FeO.

A paper on the "Combining of Chlorine and Hydrogen" was presented by Professor Bodenstein of Hanover, dealing with the influence of light, heat and alpha radium rays and oxygen, on the reaction velocity, as investigated by Drs. Taylor and Dux. Their work was interrupted by the war, but their results are given as far as obtained.

Two papers on analysis were presented, one by Prof. W. Böttger of Leipzig, on the determination of small amounts of mercury salts in weak solutions, and a paper on metallic calcium and its application in gas analysis by Professor Sieverts of Leipzig. Prof. Walter Nernst demonstrated the application of alternating currents to bridge measurements, for instance, for determining dielectric constants. By the use of the loud-speaking Siemens telephone and inductor of the Telefunken-Gessellschaft a loud sounding system can be arranged suitable for demonstration purposes. The physical chemistry of food was taken up in a paper by Geheimrat Prof. Theodor Paul of Munich, who described the use of carbonate of lime for neutralizing the acid in wine. A paper by Prof. G. Meyer of Freiburg described the results of Dr. H. Stocker on the surface tension of pure water and salt solutions. The double refraction of vanadium pentoxide was discussed in a paper by Prof. H. Freundlich of Braunschweig. The reaction velocity of ideal gases was discussed in a paper by Prof. Max Trautz, of Heidelberg. A paper on passivity phenomena in the anodic production of halogens and the cathodic deposition of iron metals in solution was presented by Hofrat Prof. F. Foerster of Dresden. Colloidal gold was discussed in a paper by Prof. Richard Zsigmondy, and Prof. H. Goldschmidt of Kristiania, presented a paper on the alcoholization of salts. The darkness of ink on paper was discussed in a paper by Dr. W. Mecklenburg, of Berlin-Lichterfelde. A paper on the parallelism between electric light effect and Volta effect was presented by Prof. Krüger of Danzig. A paper on capacity of liquid insulators was presented by Professor Holde of Berlin. A paper on the gas content of the Taunus rocks and its relation to the springs of Wiesbaden was presented by Prof. F. Henrich.

The General Chemical Co. has just awarded to John W. Ferguson Co., engineers and contractors, Paterson and New York City, a contract for the construction of a manufacturing building at their Hudson River Works, Shadyside, N. J., across the Hudson River from New York City. This building will be two stories high 54 ft. by 55 ft. A 20-ft. by 20-ft. sq. tower rises from one corner, 30 ft. above the main building.

The Williams Apparatus Co. of Watertown, N. Y., has been formed to take care of the increased business of the Williams improved gas apparatus, as well as other high-grade specialties which the company is bringing out. The need of a compact, portable instrument by which an accurate gas analysis could be made quickly has been felt for some time and the popularity which the Williams apparatus has attained in a comparatively short time is an indication that it meets a real want. The Williams Apparatus Co. has expert glass-blowing and repair facilities both for the manufacture of its own products and special service of its patrons. In view of the present European war conditions these facilities are of particular timely value.

The **tin smelter** erected by the American Smelting & Refining Co. at Maurer, N. J., to smelt Bolivian tin ores, will be ready to operate in January.

The Character and Extent of Atmospheric Pollution in English and Scotch Towns

With Notes Upon a New Type of Recording Actinometer

BY JOHN B. C. KERSHAW

The issues of METALLURGICAL & CHEMICAL ENGINEERING for June and November, 1913, contained a detailed account by the present writer of the aims and work of the London Committee for the Investigation of Atmospheric Pollution, together with an illustrated description of the standard type of soot and dust collecting gage.

The method depends upon the use of an enlarged type of rain gage for the collection of the whole of the monthly rainfall at selected localities in each town. The soluble and insoluble impurities contained in the collected rainwater are then separated and are estimated by chemical methods. In some towns only one gage is installed, but in London, Glasgow, Birmingham, Sheffield and Manchester there are several gages placed at different points. Manchester, indeed, has ten gages in use in different parts of the city and its surrounding districts, and is also undertaking another investigation which will be referred to later.

The observations have now been carried out in sixteen English and Scotch towns for twelve months, and valuable information has been collected bearing upon the amount and character of the pollution existing in the air of the larger industrial cities. An official report upon the whole of the collected figures will be published by the committee at a later date, but the present article represents the writer's analysis of some of the figures and the conclusions drawn from them. The importance of knowledge of the local conditions existing in each town is shown by the comments on the Liverpool results.

RESULTS IN TEN ENGLISH TOWNS FOR THE SIX WINTER MONTHS OF 1914-1915

Table I contains a summary of the more important figures for ten English towns covering the six winter months, October to March, 1914-1915. It will be seen that Oldham occupies the place at the head of the table, with a soot and dust fall in the six months of 532 tons per square mile, equivalent to 1064 tons per square mile per annum. Birmingham (central) comes next, with a fall of 382 tons in the six months, while Bolton, Sheffield, Liverpool, Newcastle, Manchester and London follow in the order named.

TABLE I—THE SOOT AND DUST FALL OF ENGLISH TOWNS
FALL OF SOLID MATTER, OCTOBER, 1914, TO MARCH, 1915.

Name of Town or City	Tons per square mile. Total Solids	Tar, Soot and Ash
Oldham	532	364
Birmingham (Central)	382	252
Bolton	346	131
Sheffield (Attercliffe)	321	193
Liverpool	286	167
Newcastle	265	156
Manchester (Technical School)	263	156
London (Golden-Lane)	249	128
York	158	78
Malvern	32	5.88

York and Malvern occupy, as might be expected, the places of honor at the bottom of the table, with total soot and dust falls of 158 and 32 tons respectively. The latter figure is only one-eleventh that of Bolton and only one-seventeenth that of Oldham, and it shows what great scope exists for improvement in the atmospheric conditions of the Lancashire manufacturing towns.

London occupies a comparatively good position, ranking below all the Lancashire and other manufacturing towns of the north in the cleanliness of its atmosphere.

Examination of the deposit shows that the insoluble solid matter that has fallen during the winter months in the ten towns dealt with is composed of tar, solid car-

bonaceous particles and ash, and that the relative proportions of these three constituents do not vary very considerably in the different towns. Thus at Oldham, the insoluble solid deposit contained 1.5 per cent of tar, 29 per cent of carbonaceous matter, and 69 per cent of ash, while at York the percentages were 2, 30 and 68.

As a general rule, the percentage of ash is highest and the percentage of tar and soot lowest in manufacturing districts, since when fuel is burnt under boilers or in furnaces there is a tendency for the smaller particles of unconsumed fuel to be carried up the chimney and to be discharged as fine ash into the atmosphere. The temperature of the furnace is (or ought to be) sufficiently high to consume all the hydrocarbon gases and to prevent the formation of smoke and soot. In residential districts with old-fashioned grates, the opposite conditions prevail, and the proportion of tar and carbonaceous matter present in the smoke is generally higher than in factory districts.

The figures showing the percentage composition of the solid deposit collected by the standard gages in ten English towns and cities are gathered together in Table II, and on the whole support this view.

Table II—The Soot and Dust Fall of English Towns.
Proportions of Insoluble Solids, October, 1914, to March, 1915.

	Tar		Carbon		Ash	
Name of Town or City	Weight in tons	Per cent of total fall	Weight in tons	Per cent of total fall	Weight in tons	Per cent of total fall
Oldham	5.57	1.5	109	29	249	69
Birmingham (Central)	3.20	1.3	67	26	182	72
Sheffield (Attercliffe)	2.46	1.3	61	32	129	66
Liverpool	4.37	2.6	35	21	128	76
Newcastle	2.05	1.3	59	37	96	61
Manchester (Tech. School)	1.80	1.1	51	33	103	66
Bolton	1.63	1.2	31	24	99	74
London (Golden-Lane)	1.15	.90	49	38	78	61
York	1.60	2.0	24	30	53	68
Malvern	0.05	1.0	2	34	3.83	65

The average percentage ash fall in the five typical manufacturing towns, Oldham, Birmingham, Sheffield,

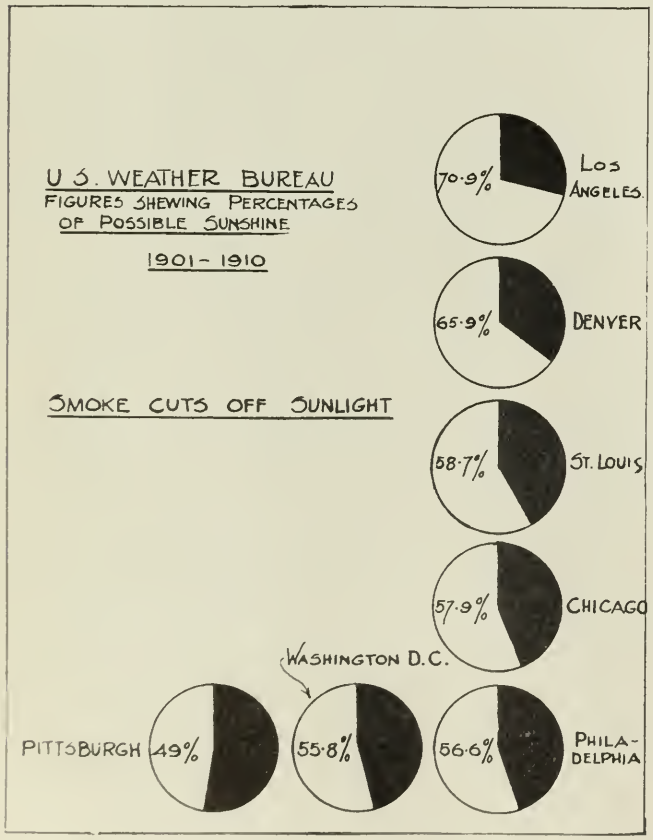


FIG. 1—SUNSHINE DIAGRAMS FOR SEVEN AMERICAN CITIES

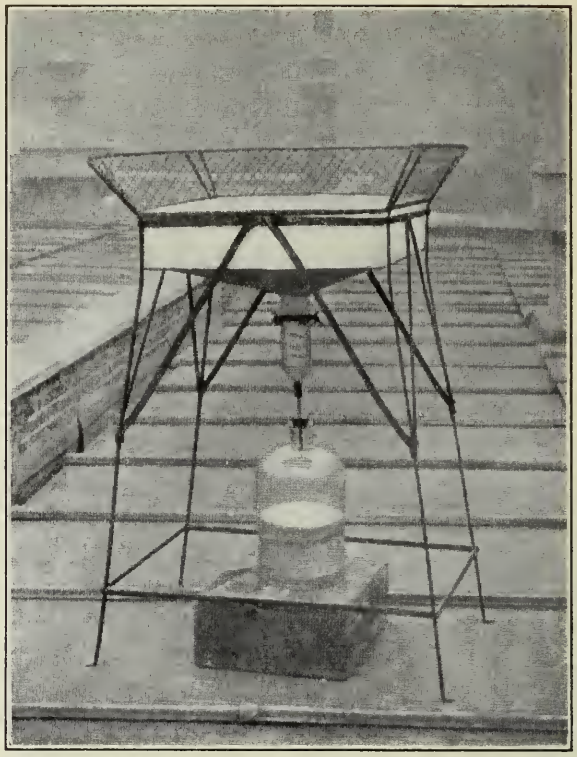


FIG. 2—THE ORIGINAL SOOT AND DUST GAGE USED FOR THE LANCET EXPERIMENTS IN LONDON, 1910-1911

Manchester and Bolton, is 69 per cent, as compared with 64 per cent for the four towns which may be classed as seaports or as residential in character, namely, London, Newcastle, York and Malvern. The tarry and carbonaceous constituents of the soot and dust fall in the four latter towns amounted to 36 per cent of the whole deposit, as compared with 31 per cent for the five manufacturing towns.

Liverpool seems to occupy an isolated position in this respect, for the percentage of solid matter in its soot and dust fall was higher than that of the manufacturing towns and its percentage of carbonaceous matter extremely low. This peculiarity is most probably due to the fact that in hot weather, under certain conditions of the wind and tide, a large quantity of fine sand is carried over the city from the sandy shores that lie on its north and northwest side. This fine sand falls by its own weight or remains suspended in the atmosphere until carried down with the rain, and tends to increase the incombustible solid portion of the deposit.

RESULTS IN SIX SCOTTISH TOWNS FOR THE WINTER MONTHS, 1914-1915

Turning now to a consideration of the returns that have been received from Scotland, we find that only six towns have carried on the observations during the winter of 1914-1915. These observations were interfered with greatly by frost and by breakage of the collecting bottles, and therefore they do not cover the whole period, nor are they strictly comparable with the English results.

The figures, so far as they are available, have been calculated out as tons per square mile, and are gathered together in Table III.

Assuming that the soot and dust fall for the shorter periods would increase proportionately for the whole of the winter, we find that the relative positions of these five towns are Glasgow, Paisley, Greenock, Stirling and Leith. Glasgow (Blythswood Square) possesses a total soot and dust fall of 327 tons, and ranks equal to Shef-

field (Attercliffe) in Table I, while Leith has a total fall of 147 tons in the six winter months, and would be placed below York and Exeter in Table I. The observations made by Chief Inspector Fyfe in the winter months of 1910-1911 gave the same relative positions for the four towns—Glasgow, Paisley, Greenock and Stirling—and are thus confirmed.

TABLE III—FALL OF SOLID MATTER IN SIX SCOTCH TOWNS DURING THE WINTER MONTHS OF 1914-1915.

Name of Town or City	Tons per square mile Total Solids	Tar, Soot and Ash	Remarks
Glasgow (Blythswood Square)	109	49	Two months
Glasgow (average of 7 stations)	79	28	Two months
Greenock	116	55	Three months
Stirling	84	38	Three months
Paisley	174	96	Four months
Leith	98	55	Four months

SUMMER AND WINTER RESULTS COMPARED

In view of the greater amount of fuel burnt in all large towns during the winter months of the year, and of the longer hours of darkness, during which it is possible for lazy or negligent firemen in factories to emit thick black smoke without being caught or fined, the soot and dust fall might be expected to be much heavier in the winter than in summer, and the observations confirm this expectation.

TABLE IV—THE SOOT AND DUST FALL OF ENGLISH TOWNS THE TOTAL FALL OF SOLID MATTER IN THE WINTER AND SUMMER MONTHS COMPARED.

Town	Tons per square mile in six months Summer Months April to September, 1914	Winter Months October, 1914, to March, 1915	Percentage Increase or Decrease
Liverpool	299	286	— 5
Newcastle	209	265	+ 27
London (Golden-lane)	145	249	+ 72
York	120	158	+ 32
Malvern	34	32	— 7

Table IV contains a summary of the results obtained by adding together the soot and dust fall in several towns for the six summer months of 1914, and comparing the aggregate with the fall during the six winter months.

Only five towns had completed twelve months' observations in last March, and three of these, namely, Newcastle, London and York, showed a considerable increase in the aggregate soot and dust fall for the six winter months of the year, the increase ranging from 27 per cent in Newcastle up to 72 per cent in London.

Liverpool provides an exception to the general rule, the winter soot and dust fall being lower than the summer one. This unusual feature of the Liverpool returns is due probably to the same cause as that noted earlier, namely, the fine drift sand which adds to the incombustible solid matter of the Liverpool deposit. This drift sand is carried the greatest distance during the summer and early autumn gales, when the hot sun has dried the surface sand on the shores of the Mersey estuary. In the winter time the sand is never sufficiently dry to be swept up in the air and carried long distances by the wind.

COMPARISON OF THE ENGLISH AND PITTSBURGH RESULTS

The figures given in the above tables may be usefully compared with those collected in Table V and given in the course of an article by Mr. J. J. O'Connor upon Pittsburgh's soot and dust fall, which appeared in this journal in April, 1914 (Vol. XII, page 247). The principle of the method used for collecting the soot and dust was similar, but the Pittsburgh gage was much smaller in size than that used in England.

TABLE V—SOOT AND DUST FALL IN TONS PER SQUARE MILE PER YEAR IN PITTSBURGH, U. S. A. (BREMNER), APRIL, 1912, TO MARCH, 1913

Station No.	Composition of Soot: Tar Tons	Fixed Carbon Tons	Ash Tons	Fe_2O_3 Tons	Total Tons
1	13	131	306	145	595
2	16	713	809	412	1,950
3	10	202	189	269	670
4	19	417	844	380	1,660
5	21	357	704	548	1,630
6	4	322	343	309	978
7	8	300	309	195	812
8	7	286	419	210	922
9	5	211	344	188	748
10	3	274	336	108	721
11	8	391	378	218	995
12	7	200	333	153	693

Average of twelve districts.....1,031 tons

The worst of the English towns, namely, Oldham, with a winter soot and dust fall at the rate of 1064 tons per square mile per annum, has, therefore, an atmosphere as dirty as that of Pittsburgh, with an average fall of 1031 tons per square mile per annum; whereas Sheffield, the center of the English steel-making industry, even in its dirtiest district of Attercliffe,

FIG. 3—THE STANDARD SOOT AND DUST GAGE AT LIVERPOOL, 1914

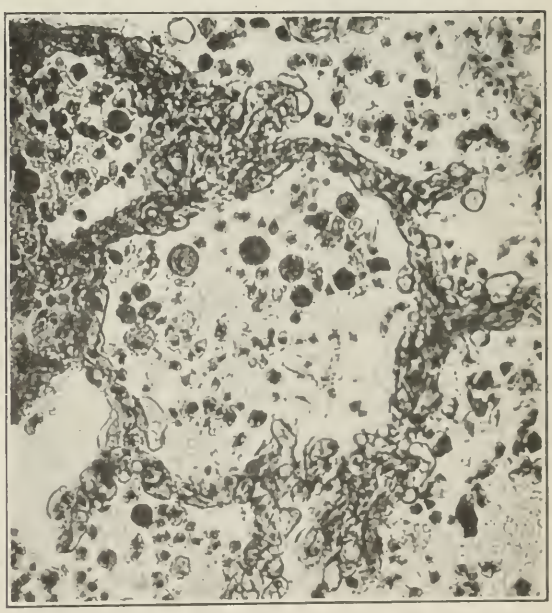


FIG. 4—A SECTION OF THE HUMAN LUNG, SHOWING SOOT DEPOSITS

shows a fall of only 642 tons in the twelve months, and is therefore far cleaner as regards its atmosphere than Pittsburgh. Possibly had the observations been carried on over a wider area at Sheffield, especially on the eastern side of the city, the results would have approximated more to those of Pittsburgh, for the prevailing winds at Sheffield are from the west and southwest.

In view of these results and facts, it is interesting to note that at the International Conference for the Prevention of Smoke, held in Pittsburgh in September, 1913, a committee was appointed to co-operate with the London committee in order to arrange for the introduction of the standard method of making these soot and dust observations in America. Mr. E. P. Roberts, the chief smoke inspector of Cleveland, was made chairman of this committee, and it may be hoped that shortly figures similar to those given in Tables I, II, III and IV will be available for some of the leading towns and cities of America.

THE SPECIAL INVESTIGATIONS AT MANCHESTER

The sanitary committee of the Manchester City Council in December, 1912, appointed an air pollution advisory board for the purpose of investigating and reporting upon the conditions of air pollution within the city area, and the first report of this advisory board to the sanitary committee, which has been recently published, forms a most valuable contribution to the literature of air pollution in towns. The board consists of the members of the sanitary committee, strengthened by other members of the City Council, and by a number of outside members of engineering and scientific societies especially interested in the smoke problem. It has no administrative powers, but is concerned solely with research and educational work.

For the purpose of more fully carrying out its objects, four sub-committees have been appointed, dealing with the *chemical, statistical, legal* and *engineering* branches of the problem. The chemical sub-committee, of which Prof. H. B. Dixon of Manchester University is chairman, has made observations upon the loss of light due to the suspended solid impurities in the air of the city by three methods. A recording actinometer devised by Prof. Haldane Gee and Mr. W. C. Jenkins of the Godlee Observatory was used for some of the observations. The results obtained with this instrument at three different observation stations during July, August and September (1914) showed that the average intensity of the sunlight at Crewe was nearly 20 per cent greater than in the Whitworth-street Garden in the city of Manchester, and that on the roof of the School of Technology (100 ft. high) it was 12.6 per cent greater than at the ground level. In order to obtain records from some place well outside the local area, it has been arranged to install one of these recording actinometers at Abergele, in North Wales.

The instrument (see Figs. 5 and 6) consists of a fixed metal cylinder, 6 in. in diameter and 3½ in. long. This cylinder is open at the bottom, but is closed at the top with a lid, having on its circumference a scale of hours and around its edge a scale of one-quarter hours. By the use of a clamping device photographic paper can be secured evenly on the surface of the drum. The lid is fixed to a curved metal upright supported on the wooden base of the instrument. The top of the upright is graduated from 50 to 55 deg., corresponding to local values of latitude. This enables the axis of the cylinder to be fixed at the required latitude by moving the curved arm until an index mark is at the right angle.

Concentric with the fixed cylinder is a movable one of a little larger size. On the bottom is a clock, with its driving axis passing through a hole in the metal bottom of the cylinder. This axis passes into a hole in a rod, and when the axis is held by turning a clamp screw, the outer cylinder, with its clock, revolves around the inner cylinder once in twenty-four hours. The clock runs for seven days, and after adjustment keeps good time. It may be noted that in the actinometer the axis is held and the clock rotates. This arrangement is the reverse of an ordinary clock.

To keep the cylinders concentric, a central rod is fixed to the center of the upper cylinder, and pivots in a central hole in the top of the clock case. On the rotating drum there are two fixed metal jaws provided with a slit between them. This slit is wider at the middle and tapers each way.

When in use the instrument must be placed with its axis in the geographical meridian, and the slit is brought opposite to the mark indicating solar time. The motion of the slit will then follow the sun, and the

FIG. 5—NEW FORM OF ACTINOMETER

FIG. 6—NEW FORM OF ACTINOMETER—WORKING PARTS

intensity of the light will be indicated by the degree of blackening of the paper.

The type of paper best for the purpose has been the object of many experiments and inquiries. So far as the experimental work has been completed, it has been found that a gas-light paper that has been treated with a 5 per cent solution of resorcin, containing ½ per cent of glycerine, is the most suitable paper for general use. The paper is sensitive to ultra-violet light, and to a certain extent toward the red end of the spectrum. The standard paper is prepared by the Ilford company.

It is proposed that all the exposed papers be sent to the School of Technology for examination and scaling. Much information can be obtained by the simple inspection of the records, but in order to obtain numerical values the surface brightness is measured by the aid of a portable photometer called a lumeter. The surface brightness is found to be, within certain limits, inversely proportional to the intensity of the received light. Where there is much variation in the daily record, the average value can be obtained by rotating the paper by means of an electric motor, and then reading off the resultant tint with the lumeter.

The ideal position for the actinometer is close to the ground, and such that the light is not obstructed from sunrise to sunset. It is difficult to obtain such a situation, especially in the city and suburbs, and although desirable it is not absolutely necessary, for useful observations can be taken even when freedom from obstruction is only for a part of the day. It is essentially important to place the instrument in the charge of persons who are accustomed to the regular use of instruments. The actinometer gives the intensity of the light directly received from the sun.

THE CONNECTION BETWEEN SUNLIGHT, PURE AIR AND HEALTH

In concluding this article a quotation may be given from the words of a famous scientist as to the intimate relation that exists between sunlight and health, and as to the effects of the soot and dust suspended in the atmosphere in screening off the active rays of sunlight from crowded city streets and tenements. Sir Oliver Lodge, the principal of Birmingham University, has stated:

"Under present conditions the greater part of humanity in England lives under a thin pall of obscure material, through which a certain amount of light and heat can pass, but which effectually screens the health-giving and disease-destroying actinic rays of the sun. Accordingly, frequent excursions in the country are needed for the preservation of even a moderate or residual amount of robust health, while the multiude condemned to live under unwholesome conditions suffer both in themselves and their children to a grievous extent."

This screening effect of a dust-polluted air is far greater than is imagined, for direct experiments in Manchester have proved that on a sunny day *no less than* 12 *per cent of the sunlight is cut off in the last* 100 *ft. of the atmosphere.*

There are three essential factors in the preservation of good health, namely, pure water, pure food, and pure air; and it is satisfactory to find that at last the importance of the third factor is being recognized. The soot and dust suspended in the atmosphere are disadvantageous and harmful to the living organism in several ways. In the first place by diminishing the amount of sunlight which falls upon the earth they directly lower the vitality of the human organism and diminish its power of resisting disease. Cohen has shown that in Leeds the smoky atmosphere cuts off from 25 per cent to 40 per cent of the sunlight, and the Pittsburgh and Manchester investigations have confirmed these results. The soot and dust suspended in the atmosphere also enter and choke up the pores and cells of the lung tissue to such an extent, that the rapid assimilation of oxygen by the blood, and discharge of CO_2 and other waste products, is checked. Doctors can always tell, by a post-mortem examination, from the color of the lung tissue whether the man has lived chiefly in the town or the country during his lifetime, and the shortened life of town-dwellers is partly due to this cause.

Finally, direct sunlight and pure air are now recognized as natural germicides, and the soot and dust suspended in the atmosphere therefore aid the propagation of all infectious diseases by promoting the conditions which are favorable to bacterial life.

The writer's thanks are due to Mr. J. J. O'Connor and to the directors of the Mellon Institute, of the University of Pittsburgh, to Professor Beattie and to Dr. Hope of Liverpool University, and finally to Professor Gee and Mr. W. C. Jenkins of Manchester, for information and for the loan of the photographs used in the preparation of this article.

Liverpool, England.

Recent Chemical and Metallurgical Patents

Iron and Steel

Low-Phosphorus Steel from High-Phosphorus Iron.—According to a process of ALVA C. DINKEY low-phosphorus steel is cheaply produced from iron containing phosphorus above the permissible or specified limit, as follows: A quantity of limestone and ore or other oxide of iron is charged into a furnace, the limestone amounting to about 5 per cent and the ore or oxide to about 15 or 20 per cent by weight of the metal to be treated. The charge is heated until it is at a red heat or is pasty and even fused. The charge of pig iron in a molten condition is then poured into the furnace as rapidly and as nearly at one time as possible. This causes an active reaction and a rapid production of basic slag, and the materials being at a comparatively low temperature, the iron oxide oxidizes, the phosphorus, silicon and manganese in the pig iron with extreme rapidity and at the same time oxidizes a slight portion of the carbon. At the end of about one hour, the phosphorus will be substantially eliminated, that is, reduced to about 10 per cent of its original content. The furnace is then tapped and the partly refined metal removed therefrom to a mixer or storage vessel for subsequent treatment in acid Bessemer converters. The iron will be treated in the preliminary furnace in about 50 to 100-ton lots and as the storage vessel has a much greater capacity (500 or more tons), a large quantity of partly refined or semi-finished metal can be stored therein. (1,162,755, Dec. 7, 1915.)

Sulphuric Acid

Contact Process for Sulphuric Acid.—In the contact process of making sulphuric acid it has been the custom to preheat the sulphur dioxide and air to about 400 deg. C. before passing them through the converter which contains trays of the catalytic mixture, usually $MgSO_4$ with 0.2 per cent platinum. The platinum acts as the catalyser. In the process there are three distinct steps, (1) the drying of the gaseous mixture, (2) the heating of same, (3) the treatment with the catalyser. In order to perform all these operations in one step a process has been patented by CLARENCE J. BROCKBANK of Niagara Falls, Ontario, Canada (assigned to the Carborundum Company). The gases are passed

through an acid-proof pipe in which is placed a porous diaphragm made of fine carborundum crystals (such as described in patent 992,698 of Frank J. Tone, May 16, 1911). This carborundum diaphragm is previously impregnated with platinum by immersing it in a solution of platinum chloride and heating whereby the chlorine is driven off and the platinum remains. This diaphragm is heated by joining it to electric terminals, as shown in Fig. 1. This process provides a means of controlling

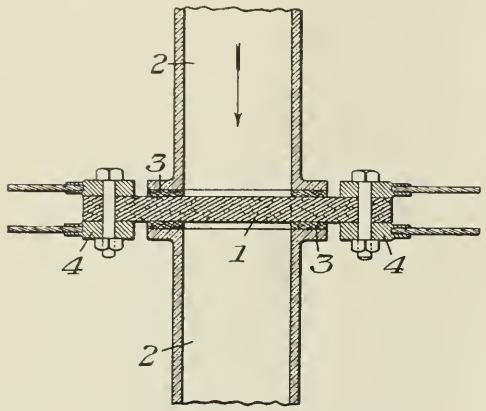


FIG. 1—CATALYTIC DIAPHRAGM

the temperature accurately (between the limits of 400 and 800 deg. C.) and the gases are instantly converted and a better yield is claimed to be attained. The carborundum plate is not attacked by fuming sulphuric acid and in case it is fouled by arsenic may be restored by immersing in aqua regia and heating. (1,157,293, Oct. 19, 1915.)

Gold and Silver

Hydrolysis of Alkaline Cyanides.—In addition to the action of cyanicides in destroying the efficacy of alkaline cyanides as solvents for gold and silver, "the principal loss is due to the formation of hydrocyanic acid by hydrolysis of the simple cyanide solution," according to letters patent granted to Mr. Hugh M. Leslie, of Glasgow, Scotland. The patentee states that he has arrived at this conclusion as the result of extensive experiments to determine the loss of cyanide in the treatment of ores. The hydrocyanic acid evolved as the result of this hydrolysis is constantly passed into the atmosphere and lost. It is claimed that the presence of a large excess of caustic alkali in the ore pulp will not prevent this hydrolytic action. The inventor proposes, therefore, to recover this hydrocyanic acid and make it available for further dissolution of metal by covering the tanks used in the cyanidation of ores and conducting the evolved gas to absorption tanks where the hydrocyanic acid may be fixed in alkali. When thus recovered the cyanide is useful for further work on ores. A modification of his proposal is to arrange covered agitators and dewaterers in such a way that the pulp is gradually raised from one machine to the next by means of air-lifts, the hydrocyanic acid gas collected being introduced to the agitators with the air at each lift and thus caused to act on the pulp. (1,158,513-4, Nov. 2, 1915.)

Filter.—A filter of the drum type, for separating solids and liquid contained in an ore pulp, is shown in section in Fig. 2, being the patented invention of William P. Lass of Treadwell, Alaska. The filter leaves 79 are stationary, resting on rollers 80 and supported between guides 83. Spray pipes 87 are provided for the purpose of spraying the leaves and discharging therefrom the cake formed in the filtering operation. Pulp to be filtered enters the bottom of the drum at 33.

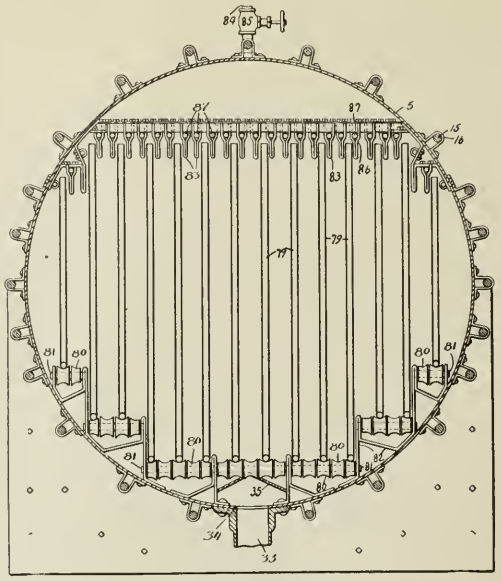


FIG. 2—FILTER

Compressed air is supplied to the drum by the pipe and valve 84, 85. When the pulp has filled the drum to a point above the filter frames, a valve is opened to permit the filtrate to run from the press through a pipe not shown. After a cake has been formed of the desired thickness, compressed air is admitted through 85, forcing the remaining pulp back out of the press through an exit pipe. Wash solutions may be introduced into and removed from the drum in the same manner, and after the cake has been washed it is blown from the filter leaves by reverse pressure of air or steam, and the discharge is facilitated by sprays of water from the pipes 87. The tailing pulp can be removed from the drum by screw conveyor or sluiced by the water sprayed from the pipes. (1,144,854, June 29, 1915.)

Copper

Flotation of Sulphidized Minerals.—A method of treating low-grade oxidized copper ores is disclosed in the specifications of a patent granted to Henry B. Hovland of Duluth, Minn. He proposes to dissolve the copper in sulphuric acid, and then sulphidize the metal by adding to the pulp a mixture of calcium sulphide and ferric sulphate, the latter to facilitate the conveyance of the sulphur to the metal to be sulphidized. The copper thus treated can then be recovered as a concentrate by flotation. Calcium sulphide is mentioned as the sulphidizing agent as it is a cheap material, easily prepared from lime and sulphur, or by reducing gypsum. (1,159,942, Nov. 9, 1915.)

Precipitating Copper from Solution by SO_2.—A suggestion for recovering metallic copper from its solution as a sulphate is contained in a patent granted to George D. Van Arsdale of East Orange, N. J. After the copper is dissolved from its ore the solution is separated from the gangue in any desired manner, and is then saturated wth sulphur dioxide to effect a precipitation of metallic copper under certain conditions of heat and pressure. Sulphuric acid is regenerated in the precipitating process and can be used for the treatment of additional ore. In the treatment of ores containing practically no soluble constituent except copper, an excess of free sulphuric acid is generated. It is advantageous to neutralize this excess of acid, or part of it, and thereby control the amount of copper precipitated. Since two molecules of H_2SO_4 are formed for every molecule of copper precipitated, and if it is de-

sired to neutralize one of these by the use of CaO, it will be necessary to add CaO in the ratio of the molecular weights of copper and lime, or 63:56. The proportionate amount of lime used will vary with the conditions which it is desired to maintain in the solution, or in other words, in accordance with the yield of copper required or the amount of free acid which is to be left in an unneutralized condition. (1,147,466, July 20, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Development of an Acid-Resisting Alloy.—An interesting paper on a new acid-resisting alloy was presented by Prof. S. W. PARR of the University of Illinois at the meeting of the American Institute of Metals at Atlantic City, Sept. 28, 1915. The increasing cost of platinum prompted the author to attempt to find an alloy that could replace it in some uses. The problem contained many difficulties as so many properties were required viz.: resistance to acids, density, strength, workability and resistance to corrosion. The "cut and try" method had to be resorted to for the most part, although the guiding theoretical consideration was to arrange the constituents so that as far as known the electro-positive and electro-negative properties would neutralize each other and produce a potential of zero. The lack of practical working data on this question and the ever presence of impurities and their great effect made exact applications of the theory out of the question.

An alloy was, however, found with a degree of resistivity which had hardly been thought possible. The unit of reference for measuring the amount of corrosion was adopted as follows: A standard disk of the alloy was prepared having 10 sq. cm. of surface. This was submerged for a given length of time, usually twenty-four hours in nitric acid of approximately 25 per cent HNO_3. The loss in weight was calculated to the amount which would be represented for an area of 100 sq. cm. per hour.

In test No. 23 a small casting of simple form was secured from which the test piece showed a loss in weight referred to this unit of surface and time of 0.03 mg. In test No. 40 a casting of more difficult form was secured weighing about 10 lb., the test piece from which gave an equally high degree of resistivity. In the last seven castings of similar size, Nos. 133 to 136 inclusive, six out of the seven standard disks did not show a weighable loss after contact with the nitric acid for twenty-four hours.

The casting and working properties of the alloy had to be promoted in all of the modifications. At first thought this would seem to multiply the difficulties. On the contrary it proved to be more of an advantage than otherwise. That is to say, each additional element would tend to lower the melting point of the alloy and reduce the tendency to form an open texture or coarsely crystalline structure. If the resulting composition seems to be unnecessarily complex, the above statement may be a partial reason for that result.

An analysis (by S. A. Braley and F. E. Rowland) of a representative sample is as follows:

Cu	6.42
Mn	0.98
Si	1.04
W	2.13
Ni	60.65
Al	1.09
Fe	0.76
Cr	21.07
Mo	4.67
	98.81

Carbon and boron not determined.

The casting of the alloy proved to be quite as serious a problem as the development of the composition. The melting point is approximately 1300 deg. C. The furnace must be capable of readily attaining the temperature of molten nickel, say 1600 deg. When thoroughly liquid the alloy pours readily and fills the mold perfectly but the freezing point is so quickly reached that feeding of the casting from risers, to make up for shrinkage, is practically impossible. Moreover the shrinkage is so excessive that cracks and hollow spots are very difficult to avoid. This feature can be perhaps better appreciated when it is noted that the most important instrument in mind for use of the alloy was a calorimeter bomb, which consists essentially of a chamber of approximately 35 cu. in., which must retain absolutely without leakage, a gas at an average pressure of 25 to 30 atmospheres.

Here again the very complexity of the composition has probably been the chief factor in securing a metal which could by any means be cast in the dense, homogeneous form required. It works about the same as tool steel. The interior surfaces of the bomb and cover show no trace of corrosion after use in over 1500 determinations using the apparatus in determining the heating value of coals. In each determination there is generated a considerable quantity of nitric and sulphuric acids which condenses on the interior surfaces of the bomb. Under the prevailing conditions of heat and high oxygen pressure the best possible conditions exist for the promotion of corrosive action.

Attempts to draw the alloy into wire and roll it into sheets have been only partially successful, but sufficient to show the likelihood of success when the conditions for proper annealing are better understood. The tensile strength of the cast metal is approximately 50,000 lb. per square inch. The name suggested for the alloy is "Illium."

Gold and Silver

Zinc-Dust Precipitation Tests.—An A. I. M. E. paper presented at San Francisco gives a discussion of observations made by NATHANIEL HERZ on laboratory tests of a large variety of zinc-dust samples. The author used the efficiency test of W. J. Sharwood, as follows:

"A solution of potassium silver cyanide is prepared by dissolving 10 grams silver cyanide (AgCN) and 5 grams of 90 per cent potassium cyanide in a little water and diluting up to 1000 cc. It is then adjusted by addition of a little more KCN or AgCN until the solution indicates from 0.12 per cent to 0.15 per cent free KCN by titration with standard silver nitrate. The titration is best made by using a 10-cc. or 20-cc. sample, adding 1 cc. of 2 per cent potassium iodide, and a slight excess of ammonia; the end point is then sharper. Or 1.5 grams of pure crystallized $KAg(CN)_2$ may be dissolved in a liter of water and 1.5 grams KCN added.

"Weigh out 0.5 gram zinc dust into a 300-cc. beaker. Add a few cubic centimeters of water and stir until zinc is well mixed, then pour in 250 cc. of the prepared solution, stirring vigorously. See that all lumps are broken up, and continue stirring for fully five minutes. Stir occasionally (at least every 10 minutes) until the end of two hours from the addition of the solution. Then filter upon an 11-cm. filter, wash precipitate thoroughly, sprinkle with test lead, wrap it carefully in the paper, place in a scorifier with about 20 grams test lead, burn paper cautiously in muffle, scorify five minutes, cupel at low temperature and weigh silver. Milligrams silver obtained from 0.5 gram zinc × 0.0606 = percentage precipitating efficiency."

Substitution of sodium for potassium cyanide gave no variation in results. Precipitation of gold solution gave only about one-half to one-third the efficiency observed with silver solutions. Mixed gold and silver solutions gave efficiency intermediate that of silver and gold alone, the beads containing four atoms silver to one gold. Slight variations in free cyanide present do not affect results materially, but the quantity cannot be reduced to 0.01 per cent without giving very different results. In some cases exposure of the zinc dust to moist air for several hours seemed to increase efficiency of precipitation. Other tests indicated that the oxidation of zinc dust by exposure to dry air is practically negligible. In moist air, on the other hand, oxidation may amount

to as much as 2 or 3 per cent per day, falling off as oxidation proceeds. The efficiency of precipitation is not reduced as much as commonly supposed.

Lead increases the activity of zinc in cyanide solutions, and cadmium would probably also help, though not as much as zinc. Analyses of samples showed the lead content to vary from 0.15 per cent to 5.2 per cent, and cadmium from *nil* to 3.9 per cent. Zinc oxide varied from 6.3 per cent to 17.85 per cent. Some carbonaceous matter occurs in some samples, but is inert. Carbon dioxide also occurs, but in such small quantities as to be of no material effect in precipitating calcium carbonate and thus preventing contact of zinc with cyanide solution. Some dusts contain an oily material of some kind, and such dusts are improved by exposure to air.

The author gives the following requisites in zinc dust for satisfactory precipitation: Most of it should pass a 200-mesh screen, and the fine portion should be much finer than the screen opening. Oxide should be low, although this does not necessarily indicate a good dust. Lead should be present at least over 1 per cent, and 4 per cent may do no harm. The value of the dust for precipitating purposes can be determined rapidly by testing with standard silver cyanide. If the efficiency is well over 40 per cent, the dust is satisfactory; if under 30 per cent, the dust may give poor results.

Lead

The Newnam Mechanical Lead Hearth.—A successful effort to mechanicalize the ore hearth for smelting galena is recorded by Mr. William E. Newnam of Collinsville, Ill., in a paper prepared for the next meeting of the American Institute of Mining Engineers. The field of the ore hearth in lead smelting is confined to the treatment of non-argentiferous galena containing over 68 per cent lead. The advantages of this method of smelting are the lower cost of pig lead, the immediate reduction of 55 to 65 per cent of the lead content of the concentrate, with simultaneous roasting, thus producing a small tonnage of gray slag which is an ideal feed for the blast furnace. The disadvantages of the method are the limited size of units, 4 ft. to 5 ft., requiring two men per eight-hour shift; small product per man; hot and laborious work with danger of lead poisoning from dust and fume; large flue and bag-house system required to catch dust and fume which must be re-treated.

After a careful study of the hand-hearth operation, it was decided that three things were necessary to perfect it, namely: A cool and sanitary hood; a mechanical rabbler which would effectually replace the continuous and laborious use of the hand rabble, and a lead-well attachment that would mold clean lead direct from the hearth basin with little attention on the part of the furnacemen.

Experiments were carried out on the ordinary 4-ft. hand hearth. The hood problem was taken up first; and soon a double hood was devised which gave the furnace room a clear and fume-free atmosphere, at the same time reducing the direct and radiated heat to the workmen 50 per cent. A complete cessation of sickness and an increased output were at once noted.

After a few trials a simple and effective lead well and molding device was installed.

A traveling rabbler was next put on the 4-ft. furnace, and, after numerous changes, a successful type was worked out.

This rabbling machine is hung from a carriage which travels on an overhead track, and it rabbles in one direction only, for a reason given later. The machine being in such a position that the rabble arm is at the extreme end of the furnace, a releasing lever is pulled, which starts the machine, causing the rabble arm to describe a motion which is similar to that of the hand rabble, but more effective, since there is more power behind it. As the rabble arm is withdrawn from the fire, an eccentric connected with a ratchet wheel moves the carriage forward about 4 in. for the next stroke of the rabble arm. This motion is repeated until the other end of the furnace is reached, when the machine automatically stops and withdraws the rabble arm from the fire.

Two men, a charger and a helper, operate the furnace. The helper follows close behind the rabble arm and with a long-handled shovel pushes back the loose charge, picking out the gray slag as he goes along. Close behind the helper comes the charger, who spreads a thin layer of ore on the charge as fast as it is shoveled back by the helper, adding coke breeze as needed.

Thus the fire is exposed for an instant only, and by the time the trip down the furnace is completed the end first charged is ready for the rabbling machine. It is for this reason that the rabbling is performed in one direction only. The first trip being complete and the gray slag removed from the apron, the throwing-in of a clutch causes the carriage to return without rabbling to its original position, where it automatically stops in readiness for a second rabbling trip.

Thus on each trip the fire is rabbled twenty-four times in forty-eight seconds, the return motion require twelve seconds. One horsepower is required under full load, and is supplied by a 1-hp., alternating-current 220-volt motor. The rabbling machine is simple, strong, and durable, and only requires a few minutes' attention daily.

From the data compiled it was determined that the hearth could be increased to 8 ft. in length, that it would then produce two and one-half times as much pig lead as the hand hearth; and that two men could operate it with less fatigue than that sustained by two men on the ordinary hand hearth. An 8-ft. hearth was at once constructed and from the first day of its operation it has not only realized our expectations but considerably exceeded them.

The following table is a comparison of the two types of hearth, operating side by side on the same ore, showing the average results per eight-hour shift over a period of four weeks, the labor being the same on each type. Ore charged, galena concentrates, containing 72.5 per cent lead, and 15.1 sulphur.

	Newnam Hearth, Pounds	Hand Hearth, Pounds
Dry ore charged	13,179	5,091
Lead contents	9,554	3,691
Pig lead made	6,443	2,030
Gray slag made	3,318	1,329
Per cent of coke breeze used	3.6	8.8
Rabble trips per hour	37.2	....
Percentage of Total Lead in Products		
Pig lead	67.44	55.00
Gray slag	15.18	16.20
Dust and flume	17.38	28.80
	100.00	100.00

Analysis of Gray Slag

	Pb	FeO	CaO	S	Insoluble
Newnam hearth	43.7	12.8	9.9	1.9	12.6
Hand hearth	45.0	12.2	9.0	2.6	12.2

Taking the above average runs as a basis, the sulphur elimination is calculated as follows:

Newnam Hearth

	Pounds	Sulphur, Per Cent	Sulphur, Pounds	Sulphur, Pounds
Dry ore charged	13,179	15.1	..	1,990
Gray slag	3,318	1.9	63	....
Dust	776	11.1	86	....
Burnt fume	1,552	5.9	92	241
Pounds of sulphur eliminated	....	...	..	1,749
Per cent of sulphur eliminated	....	...	..	87.9

Hand Hearth

	Pounds	Sulphur, Per Cent	Sulphur, Pounds	Sulphur, Pounds
Dry ore charged	5,091	15.1	..	769
Gray slag	1,329	2.6	35	....
Dust	497	11.1	55	....
Burnt fume	994	5.9	59	159
Pounds of sulphur eliminated	....	...	..	620
Per cent of sulphur eliminated	....	...	..	80.6

Ozone for Ventilation

The following is a report of the test of a Westinghouse air ozonizer, together with the results of the experiments on air ozonization which have been carried out by Mr. SHEPPARD T. POWELL for Messrs. Wehr and Walden, engineers, of Baltimore, Md., during the past year. The investigation was carried on under conditions ordinarily encountered in a chemical laboratory, and for this reason the results obtained may be somewhat at variance with the results of other investigators who worked under local conditions more favorable for such work. Notwithstanding this fact, the results of the tests reported are instructive in determining the efficiency of air ozonization.

The investigation was conducted to determine:

1. The efficiency of the generator in respect to the production of ozone, especially in reference to its operation under varying weather conditions and air velocities through the tubes.

2. The effect of the gas upon odors in the air and to determine the failure of ozone to remove or mask odors caused by certain compounds.

3. The efficiency of ozonized air in the destruction of bacteria and similar micro-organisms present in the atmosphere.

It was not within the scope of the laboratory to touch upon all phases of air ozonization, so that the investigation was narrowed down to these three points, as these are the all important aspects of the purification of air by means of ozone.

LABORATORY APPARATUS AND METHODS EMPLOYED

The ozone generator used in this work was the standard Westinghouse air ozonator. This generator consists of a cylindrical metal case containing four glass tubes, 2 in. in diameter and 9 in. long, on which there is a metallic coating and within the tubes is wire gauze. In the lower portion of the case is placed the step-up transformer, the high-tension leads from which are connected, one to the wire gauze on the interior of the glass tubes and the other to the metallic coating on the outside of the glass tubes, the glass tubes thus serving as the dielectrics between the metallic electrodes. The production of ozone is controlled by means of a switch so that one or more tubes can be operated at the same time.

For this work the lower half of the generator was inclosed within a practically airtight wooden box, and over the top of the generator was a metallic hood serving the purpose of a container or reservoir for the collection of samples of the gas.

A ⅛-hp. blower was used for varying the air velocity through the generator tubes, the outlet of the blower being connected directly to the wooden case of the ozonator by means of a 4-in. metal pipe. When the blower was in operation the air entering the apparatus was filtered by means of an absorbent cotton felt mat. A sketch of the apparatus is shown in Fig. 1.

The method of analysis used in determining the concentration of the gas was a modification of the Treadwell Hall method.[1] The method consists in aspirating a known volume of the ozonized air through a $2N$ potassium iodide solution contained in a specially designed absorption bottle (the volume of the sample depending upon the concentration of the ozone). To the ozonized KI solution are then added 5 cu. cm. of 1 to 3 sulphuric acid and titrated immediately with $\frac{N}{24}$ sodium thiosulphate, finishing the titration by means of starch. The concentration of the gas is reported in milligrams of ozone per liter of ozonized air, which is equivalent to grams of O_3 per cubic meter by the following formula:

$$O = \frac{AN}{R}$$

in which O is the number of milligrams of ozone per liter of ozonized air, A the number of cubic centimeters of thiosulphate solution required, N the strength[2] of the solution, and R the number of liters of gas that passed through the KI solution.

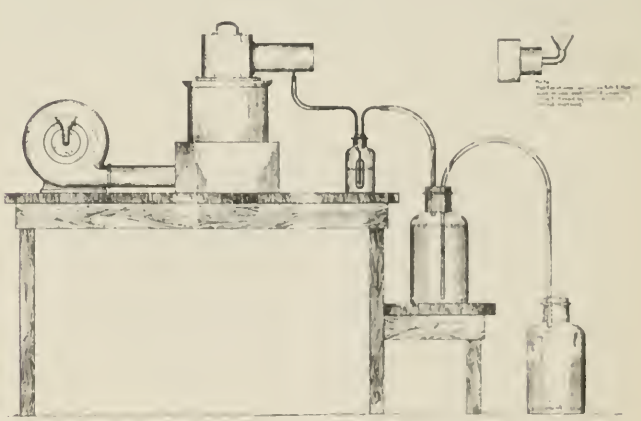
The culture medium used in the bacteriological work that was done was nitrient gelatine prepared according to the methods recommended by the A. P. H. A. for water and sewage analyses. The culture plates were incubated for forty-eight hours at a temperature of 18 deg. to 20 deg. C. There are no methods known to-day which will give an accurate count of the total number of organisms present in the air, but in all probability the method employed will give quite as accurate and reliable results as many of the more elaborate methods that have been used by investigators recently in similar experiments.

RESULTS OF EXPERIMENTS TO DETERMINE THE YIELD OF OZONE FROM THE GENERATOR

The heat generated by the transformer as well as that from the brush discharge warms the air within the ozonator so that the air entering the bottom of the drum rises, causing the ozone to leave the generator at the top of the apparatus. However, as ozone has a specific gravity somewhat higher than that of air the gas must be heated to such a temperature as to overcome the tendency of the gas to leave from the bottom of the apparatus. A number of tests were made to determine if there was any uniform rate of heating of the tubes, or uniform time element in the reversal of flow of the gas through the machine.

As it was not possible to obtain any accurate temperature reading within the tubes of the ozonizer, these tests were made by means of moistened starch iodide paper. Strips of this sensitized paper were placed opposite the openings at the bottom and top of the generator and the presence of the gas noted by the blue color formed.

In every instance the ozone passed from the bottom of the generator when the apparatus was first put in service irrespective of the setting of the switch. After running the apparatus for a time, varying from one minute to twenty minutes, the flow of the gas was reversed and flowed from the top as long as the ozonator was in operation. As would be expected, there is apparently a critical temperature at which this change



GENERAL ARRANGEMENT OF THE OZONATOR, BLOWER AND SAMPLING OUTFIT USED IN THE OZONIZING EXPERIMENTS

[1] Treadwell Hall's Analytical Chemistry, Vol. II, page 676.

[2] $\frac{N}{24}$ thiosulphate solution 1000 c.c. = 1.0 gram of O_3

1 c.c. = 1.6 milligram of O_3

takes place, but there is no uniform rate of heating the tubes under uniform atmospheric conditions and current consumption.

A great number of determinations were made of the concentration of the gas generated with each setting of the switch. From these tests it was clearly demonstrated that the yield of ozone is in direct proportion to the setting of the switch, as has been stated by the manufacturers.

The average concentration in milligrams of ozone per liter of ozonized air for each setting was as follows:

Setting	1	2	3	4
Concentration	0.0150	0.0900	0.1500	0.1800

These concentrations are very constant, the greatest variation being about 5.0 per cent, covering all tests under various atmospheric conditions.

Although it is a well-known fact that humidity in the atmosphere has considerable effect upon the yield of ozone from large installations, still tests of this apparatus in the laboratory gave no evidence of this upon the concentrations produced with very great change in the humidity of the air, as can be seen from Table I:

Table I.—Varying Humidity

Setting		1	2	3	4
Humidity	58	0.0150	0.0910	0.1500	0.1750
Temperature	68				
Humidity	76	0.0151	0.0900	0.1500	0.1800
Temperature	72				
Humidity	84	0.0150	0.0910	0.1450	0.1900
Temperature	76				

Tests made by varying the velocities of air passing through the tubes showed conclusively that the concentration of ozone was affected by the volume of air passing through the tubes. In Table II are given concentrations effected by various air velocities.

Table II.—Effect of Air Velocities Upon the Amount of Gas Produced

Setting of Switch	Temp. of Air	Humidity of Air	Concentration of O_3 Grams per cb. M.	Cu. Ft. of Air Passing Through Tubes per Minute
4	70° F.	68	0.0075	7.46
4	70° F.	70	0.0019	18.63
4	70° F.	70	0.0006	37.31
4	72° F.	70	0.0001	74.62

EFFECT OF OZONE UPON ODORS

In undertaking laboratory experiments to determine the effect of ozone upon various odorous compounds, Mr. Powell approached the subject with some doubt as to the ultimate success of the undertaking, considering the complexity of the subject.

Technical papers within the past year have been filled with lengthy reports as to the value or futility of ozone as a deodorizing agent, but as yet the results seem futile; but at least the fact has been demonstrated that practical tests are of far greater value than laboratory tests, no matter how complete or scientifically they may be conducted. For this reason the experiments that were undertaken were merely to note if ozone in sufficient concentration could remove certain of the common odors to be met with in daily work.

Temperature, humidity or other conditions are seldom, if ever, identical in different places; nor is it reasonable to expect to find the same odors present, either alone or in combination, in the same degree of intensity or in similar mixtures, so that broad conclusions have not been drawn from these tests, but they are merely reported to show the possible deodorizing effect of ozone upon certain organic compounds.

The substances used in these tests were mercaptan, skatol, oil of cloves, oil of violets, bullion cultures inoculated with sewage bacteria, cigar smoke, decayed fruit, sour milk, cheese, ammonia and hydrogen sulphide.

The details of these various tests are given in Table III.

In reviewing the foregoing work it is evident that many of the compounds causing their characteristic odors are easily oxidized by ozone, and that the products of oxidation are inodorous. As a result ozone can be depended upon to remove them from the atmosphere. Others are not so readily oxidized, but in the presence of ozone are not detected, but after the ozone has been completely used up are again evident, due to incomplete oxidation. Or as a third possibility the products of oxidation possess characteristic odors which persist in the atmosphere after ozonization.

EFFECT OF OZONE UPON THE BACTERIA OF THE AIR

In studying the sterilizing effect of ozone upon the bacteria of the air a number of determinations were made before and after ozonization. In the first series of tests a number of sterile petri dishes were exposed to the air of a room for given periods of time, varying from five hours to twenty-four, at different elevations, so as to obtain as near as possible a fair average of the number of organisms that were present in the air. Gelatine media were then put into the plates and the cultures incubated for forty-eight hours at 18 deg. to 20 deg. C. The average results of the tests are given in Table IV.

Table IV.—Effect of Ozone Upon Bacteria in the Air. Average of Ten Tests

	Time Plates Were Exposed— 5 Hours	15 Hours	24 Hours
Bacterial colonies counted before ozonization	30	41	83
Bacterial colonies counted after ozonization	3	4	5
Percentage reduction in bacteria	90	90.2	94.0

(Concentration of ozone during test 0.1500.)

The second series of tests that were made to check the figures given above consisted in passing a measured volume of air through an absorbent cotton filter and determining the number of organisms in a cubic foot of air of the room by washing a square inch of the filter material in sterile water, plating a portion of the water and counting the colonies developed upon the culture

Table III.—Effect of Ozone Upon Odors

Compound Causing the Odor	Concentration of Ozone	Intensity of Odor— Before Ozonization	After 3 Hours	After 5 Hours	After 24 Hours	Control Test (After 24 Hours)
Skatol	0.1800	Strong	Fairly strong	Fairly strong	Very faint	Positive
Mercaptan	0.1800	Strong	Strong	Strong	None	Positive
Oil of cloves	0.1500	Strong	Strong	Odor changed	None	Positive
Bacterial culture	0.1800	Strong	Strong	Very faint	Very faint	Positive
Tobacco	0.1800	Strong	Fairly strong	Faint	None	Positive
Decayed onion	0.1750	Strong	Strong	Strong	Fairly strong	Positive
Ammonia	0.1800	Strong	Strong	Strong	Fairly strong	Positive
Hydrogen sulphide	0.0900	Strong	Faint	None	None	Positive
Cheese	0.1500	Fairly strong	None	.....	.....	Positive
Oil of violet	0.0900	Strong	None	None	None	Positive
Sour milk[3]	0.1500	Fairly strong	None	.....	.....	Positive

Note—All control tests gave characteristic odors of substances used after standing twenty-four hours in a room in which there was no ozone.

[3]Although in these tests it was noted that the odor of sour milk was eliminated by the use of ozone, it has been shown that when fresh milk is sterilized by the use of ozone the odor of the gas is retained by the milk, so this has not proven a practical method of sterilization.

plates. Such a procedure is open to error, but within reasonable limits of accuracy for comparative results.

The third method employed was similar to the second, with the exception that the filter medium used was sterile sand in place of a cotton felt. This method is the one in vogue generally in making ventilating investigations.

The results of both tests are reported in Tables V and VI.

TABLE V.—EFFECT OF OZONE UPON THE BACTERIA OF THE AIR

Concentration of Ozone Used in Tests	Bacteria per Cu. Ft. of Air in Room: Before Ozonizing	Bacteria per Cu. Ft. of Air in Room: After Ozonizing for 5 Hours	Per Cent Reduction After Ozonizing
0.0075 grams per Cb. M.....	32	14	56.2
0.0019 grams per Cb. M.....	28	24	14.2
0.0006 grams per Cb. M.....	39	40	+2.5

TABLE VI.—EFFECT OF OZONE UPON THE BACTERIA OF THE AIR (SAND FILTER METHOD)

Concentration of Ozone Used in Tests	Bacteria per Cu. Ft. of Air in Room: Before Ozonizing	Bacteria per Cu. Ft. of Air in Room: After Ozonizing for 5 Hours	Per Cent Reduction of the Bacteria
0.0068 grams per Cb. M.....	41	12	70.7
0.0014 grams per Cb. M.....	36	31	13.8
0.0007 grams per Cb. M.....	46	42	8.6

Note—In tests made in the office of the same company, 100 West Fayette Street, Baltimore, Md., it was found that the total number of bacteria was reduced after ozonization by 88 per cent, while the B. Coli content of the air was reduced 96 per cent.

CONCLUSION

In summing up the results of laboratory tests of this character due consideration must be given to the fact that the conclusions reached are based upon the results of tests conducted under conditions not usually present in other places. Such results are, therefore, only relative and are of value only when considered in this way.

Regarding the production of ozone by the machine, it is believed that within reasonable limits constant at the various settings of the switch that the yield of gas is but slightly, if at all, affected by temperature and humidity conditions, or at least to so slight an extent in a small generator of this type as to be negligible. The velocity of the air passing through the tubes, however, has a direct bearing upon the amount of the gas generated, the figures obtained showing that the slower the velocity of air passing through the tubes the greater the yield of ozone.

In reference to action of ozone upon the bacteria of the air, it has been demonstrated in these tests that comparatively high concentration acting for a long period of time has a great germicidal action upon organisms in the air, but the efficiency is lessened as the concentration is reduced. The tests made, however, clearly demonstrated that even low concentrations can be depended upon to eliminate to some extent the bacteria in the air of a room.

As to the effect of ozone upon various odors, it has been shown to the satisfaction of the author that the gas will rapidly remove odorous compounds from the atmosphere, provided the substances are oxidizable and the oxidation products are inodorous. All odors are probably not oxidizable, and under such conditions there may be a masking effect due to the more powerful odor of ozone, which has been noted in so many investigations. Also the complete removal of a substance causing a characteristic odor will require a given amount of gas to complete the oxidation reaction, and if the ozone is not sufficient to accomplish this then it cannot eliminate the odor.

Concerning the effect of ozone upon the health of persons, the subject cannot be dealt with here other than to state the effect upon the author. Very high concentrations have caused a dull headache and a feeling of irritation in the throat, but under this condition the author has been subject to very high concentrations in a closed room for long periods of time. Lower concentrations, however, have not been objectionable in any way, and the author has worked for several weeks, five to seven hours a day, in an atmosphere where the odor of the gas was perceptible at all times with no detrimental effect.

In tests made at the large ozone plant there has been no complaint made by the operators as to the detrimental effect of ozone upon the health of these men, yet they have been working in an atmosphere of ozone highly concentrated eight to ten hours a day for many months; but in this case they have access at all times to outside air and do not stay continuously in the ozonizer house. The only comment that has been made by these men is to the effect that they are freer from colds since operating the ozone plant and are exposed to the gas than they were before the installation of this plant.

Oil Drying and Purifying Outfits

To obtain the best service as well as to economize in the use of oil for cooling and insulating transformers, high-tension switches, circuit-breakers, electrolytic lightning arresters, and similar apparatus, it is necessary to employ some method of cleaning and dehydrating the oil from time to time. If means for thus treating the oil are not available, it must be discarded at the time and replaced by new oil free from dirt and moisture.

Both the capacity and the voltage of transformers have been steadily increasing, making it necessary that the oil used be of extremely high quality as regards its purity and freedom from moisture.

It is well-known that the presence of moisture in transformer oil, even in the most minute quantities, very seriously affects the dielectric strength of the oil. Carefully conducted tests made by the Westinghouse Company have shown that 0.001 to 0.005 of 1 per cent (1 part in 100,000 to 20,000) will reduce the dielectric strength below the standard test value of 30,000 volts between ½-in. spheres spaced 0.15 in. apart, and 8 in. below the oil surface. Particles of dust, or other foreign matter in suspension also reduce the dielectric strength and in addition form undesirable deposits, necessitating that the oil be kept free from sediment as well as moisture.

After careful investigation of the problem of reclaiming all insulating oils whose deterioration has been caused by physical changes, or the presence of moisture, carbon or foreign substances, the Westinghouse company has developed a special type of filtering outfit for this service. In this outfit the oil to be purified is forced through several layers of specially prepared filter paper. The sediment is strained out by the first layer of paper

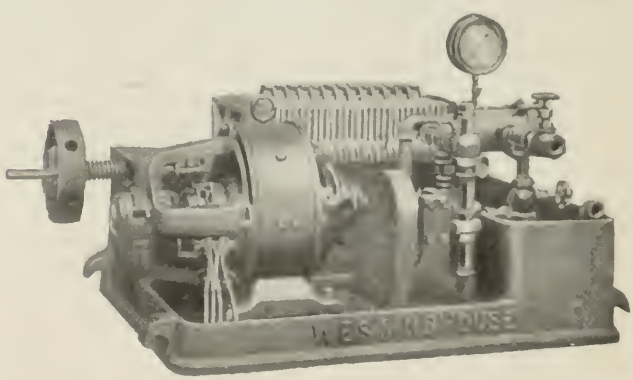


FIG. 1.—TYPE A-10 OIL DRYING AND PURIFYING OUTFIT

and the moisture is taken up by the capillary action of the paper.

While the principal class of service for which these outfits are developed is for the treatment of insulating oil, there are numerous applications for which they are well fitted. Insulating varnishes, compounds, etc., that have a sufficiently low viscosity may be cleaned and dehydrated. Machine oil of all kinds, petroleum, benzine, etc., may be effectively cleaned and dehydrated.

The complete outfit consists of filter press, motor, pump, oil strainer, pressure gage and piping. The sizes up to and including 10 gal. per minute are mounted on a neat iron base cast with a high rim that forms an enclosure and serves as a drip pan. The 20-gal. and 30-gal. per minute sizes are mounted on a structural iron base and have a sheet-metal drip pan. Electric drying ovens are supplied for drying the filter paper. The apparatus is manufactured by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Turbine Vacuum and Low Pressure Boiler Feed Pump

A combined turbine vacuum and boiler feeder pump, designed primarily for vacuum steam-heating service, has recently been placed on the market. This pump may be used equally as well on any service where both air and water, either hot or cold, have to be handled under a vacuum. The air pump and water pump are both on the same shaft and inclosed within the same casing. The air and water are separated before reaching the pump, each material being handled by itself. Other steam-heating vacuum pumps receive the water and air mixed, the separation being made under boiler pressure after leaving the pump.

The pump is shown in Fig. 1, and the complete outfit

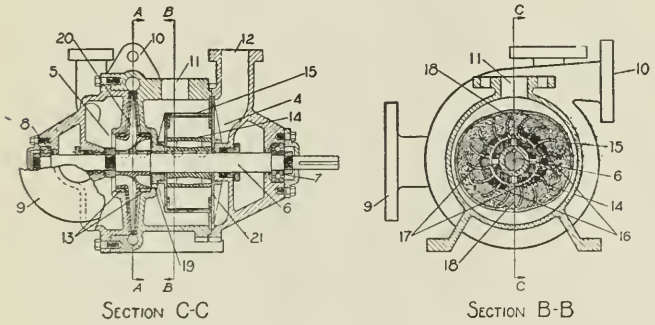


FIG. 1.—SECTIONS OF PUMPS

in Fig. 2. The pump is simple, consisting of a Nash hydro-turbine air pump and a Jennings centrifugal water pump combined in one casing. Fig. 1 shows the interior construction of the combined pump and a section of the air compressor. The air pump is at 4, the water pump at 5, both the air rotor and the water impeller being mounted on the same shaft 6, which is supported by annular ball bearings. The water inlet is at 9, the water outlet at 10. The air inlet is at 11, the air outlet at 12.

The air pump is positive in action and will give a maximum vacuum of 20 in. of mercury. A description of this pump was given in our issue of July, 1915. It consists of a rotor 14, turning freely in an elliptical casing 15. The rotor carries water around with it, the water following the casing due to centrifugal force. The water alternately receding from and surging back into the rotor, acts as a piston, drawing the air in and expelling it through ports 16 and 17, cut in the sides of the casing. A small amount of water is carried over with the air, and water is therefore constantly supplied to the pump through 19.

The water pump is a Jennings centrifugal pump, the liquid being rotated in an impeller. The interior of the pump requires no lubrication, a considerable saving in lubricant is effected, and what is more important, there is no danger of putting oil from the pump into the boiler.

In operation the heating returns, air and water, pass through strainer *B* into separating tank *C*. The water falls to the bottom of the tank *C* and passes into the centrifugal through the pipe *D*, driving the air out of the centrifugal through the pipe *L*. The pump fills with water and begins to pump, emptying tank *C*. The cen-

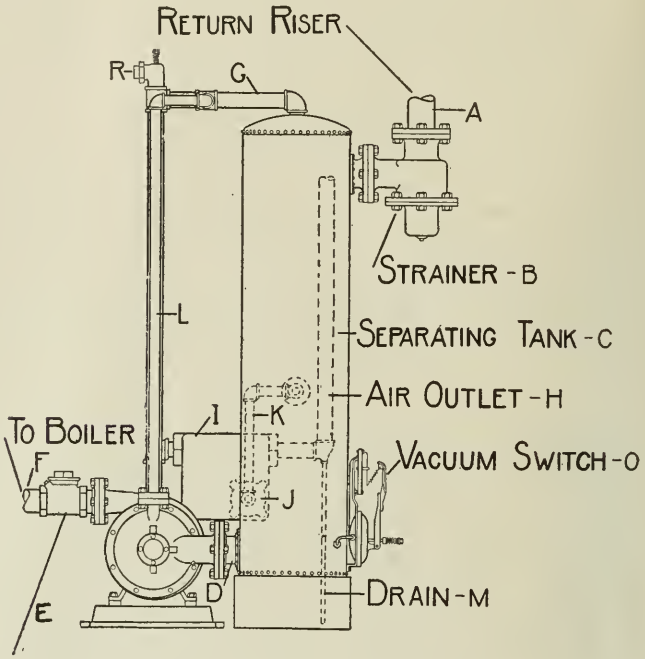


FIG. 2—PIPING CONNECTIONS

trifugal then stops as it cannot handle air, the check valve *E* preventing a back flow. The air is drawn out through *G* by the hydro-turbine.

Automatic control is furnished both for vacuum and water head. This is accomplished by means of switch shown at *O*. *I* is a separator for receiving the small quantity of makeup water from the centrifugal. The relief valve *R* is provided to prevent the vacuum from ever rising above the predetermined amount.

The pumps are furnished in five different sizes, ranging from 6 to 42 cu. ft. of air per min. and 11 to 90 gal. of water per min. at 10-in. vacuum and 10 lb. pressure. They are made by the Nash Engineering Co., South Norwalk, Conn.

Personal

Mr. **W. M. Archibald** has succeeded J. M. Turnbull as manager for the Consolidated Mining & Smelting Company of Canada, Ltd., at Trail, B. C.

Mr. **F. K. Cameron,** formerly of the U. S. Geological Survey, has been retained as chief chemist for the Utah Potash Co., which has acquired alunite deposits in Utah.

Mr. **J. V. N. Dorr** has returned to his New York office after an extended visit in San Francisco and Denver.

Mr. **Harry A. Guess,** engineer for the American Smelting & Refining Co., is on a professional trip in Chile.

Mr. **J. E. Johnson, Jr.,** has been elected chairman of the New York Section of the Mining and Metallurgical Society of America.

Mr. **Woolsey McA. Johnson** is now consulting metallurgical engineer for the American Spelter Corporation, 61 Broadway, New York City, with works at Kusa, Okla. He is acting in an advisory capacity. The American Spelter Corporation makes a high-grade spelter, zinc 99.90 per cent or more, suitable for cartridge brass, and is now producing with a capacity of eight tons of virgin spelter per day.

Mr. **Benjamin B. Lawrence** has purchased the Pelton-Doble water wheel and the Pelton-Francis turbine which were exhibited by the Pelton Water Wheel Co. of San Francisco at the Panama-Pacific International Exposition and presented them to the Columbia School of Mines. Mr. Lawrence was a member of the class of '78.

Dr. **John A. Mathews**, general manager of the Halcomb Steel Co., Syracuse, N. Y., has been elected president of the company, succeeding Mr. H. S. Wilkinson, who has resigned.

Mr. **L. H. Norton**, of Silverton, Colo., has gone to San Francisco and will spend some weeks at Douglas, Ariz., before his return.

Mr. **C. H. Vom Baur** has taken charge of the sales in this country of the Rennerfelt electric furnace, of which Hamilton & Hansell, 17 Battery Place, New York, are exclusive agents.

Dr. **J. A. Udden**, geologist of the Bureau of Economic Geology, University of Texas, has been appointed Oct. 26, 1915, director of the Bureau, the former director, Dr. **William B. Phillips**, having resigned to become president of the Colorado School of Mines.

Captain **Fred H. Wagner**, chief engineer of the Bartlett-Hayward Co., Baltimore, Md., will deliver a lecture before the Franklin Institute, Jan. 6, 1916, on "Coal Gas Residuals."

Dinner to Director Van H. Manning of the Bureau of Mines

The staff of the Bureau of Mines and the staff of the U. S. Geological Survey tendered on Nov. 20, 1915, a complimentary banquet at Washington to Mr. Van H. Manning, the new director of the Bureau of Mines, in honor of his appointment.

Mr. E. W. PARKER, who acted as toastmaster, opened the proceedings with a silent toast to the memory of the first director of the Bureau of Mines, the late Joseph A. Holmes: "He gave all that he had."

Dr. GEORGE OTIS SMITH, director of the Geological Survey, was the first speaker, taking as his theme the U. S. Geological Survey as an institution of higher learning and its graduates. Among them he mentioned John Hays Hammond, who started thirty-five years ago as an assistant in the Geological Survey, and Herbert C. Hoover, who began his career twenty years ago as a geologic assistant. The Geological Survey has supplied eminent geologists and mining engineers not only to private corporations, but to the chairs of geology in many great universities from Cambridge to Palo Alto, to the geological surveys of many States, and to many celebrated scientific institutions. Van H. Manning is a graduate of the Geological Survey of the class of 1910. "While I cannot claim credit for the Geological Survey all that Director Manning is, I am glad that the rest of his career is to be credited to the Bureau of Mines. While all of us in the Geological Survey have taken great pride in the career of Topographer Manning and Chief Clerk Manning, we are now even more proud of Director Manning, and to him we pledge our heartiest support."

The toastmaster then read a note from Dr. HOWARD KELLY of Johns Hopkins Hospital in Baltimore, expressing his regrets of being unable to be present:

"I hope this public recognition of your conspicuous services and recognized fitness for a great trust will but inaugurate a long, happy, and successful term of service. I cannot wish you better than that the mantle of the beloved Elijah may fall with increasing blessing upon the shoulders of Elisha. I love to think of your department, more even for the spirit of friendship and harmony prevailing there than for the great scientific work you are all doing."

Mr. SANFORD, editor of the Bureau of Mines, spoke for the bureau, sketching Mr. Manning's firm yet charming personality.

U. S. Senator THOMAS J. WALSH of Montana spoke in part as follows:

"A few evenings ago I opened a Bible that lay on my desk near my elbow, and, rather curiously enough without searching for it at all, I ran across the passage covering the temple of Solomon and the treasures of David which were stored therein by Solomon. The reflection would suggest that in this primitive day the earth had already given up so much of its metallic wealth that the time might come when we would see the earth's storehouse entirely exhausted.

"There is offered consolation in the fact, however, that as mining and metallurgy improve, deposits that under other circumstances were mere drops, are made available and that the percentage of the metallic extraction is continually increasing. By the best methods that were available to the Anaconda Copper Company at a period no more remote than three years ago, there was left in the tailings of its ore 0.70 per cent of copper. By treating these tailings now by the oil flotation process and by the modernized leaching process lately introduced, this loss has been reduced until now there is only 0.14 of 1 per cent of copper unrecovered, signifying a saving on every ton of ore treated by that company of 11.2 lb. of copper, which at current prices would amount to about $2, or an added extraction by that company of a daily value of not less than $25,000. By the substitution of electrical energy for steam power that company saves fifty cents per ton on every ton of the four million tons of ore that it treats annually. By this saving it is possible for that company to treat with a profit ore that carries five pounds of copper less than the lowest grade of ore that could be worked commercially before the more economic system was established and installed. Enormous amounts of low-grade ore in the Butte camp that heretofore could not be considered as a part of the company's reserve of that valuable metal have yielded enormous profits. An interesting peculiarity of that region is that the mineralization in past geologic ages was carried on so generously that very often the walls of the veins are utterly obliterated. The solutions carrying the metals penetrating through the adjacent country were such that they become ore as well as the veins, following, as a matter of course, the more remote from the main ore channels.

"So that under these improved processes and modern methods it is possible to mine a wider and wider body of ore in the neighborhood of almost all of the great ore channels in that camp, and for the same reasons the depth to which economic mining can be carried on has extended so that by the development of these processes and the installation of these new methods practically new and highly productive fields have been opened up as available just as though new deposits had been discovered. In the same way most of the great producing porphyries could not be worked at all except by the application of these new processes. The Utah Comper Company mines, mills, and markets its ore at a cost not to exceed $1.25 per ton, and at that rate it can profitably treat copper ores carrying not more than 1 per cent of copper. It annually takes more than 150,000,000 lb. of copper out of a hole that twenty years ago was entirely negligible in any account that might be taken of the world's supply of copper ore. The Conrad Placer Company operates five great gold dredges in Alder Gulch. The fabulous richness of its ore gave rise to the first stampede to Montana. The enterprise was started by Professor Shaler of Harvard. At its inauguration steam was used for power with such meager results that it was scarcely able to make expenses. In after years they have operated with electricity, with the consequence that they have been reaping such profits that they have cleaned up the entire gulch.

"Montana is to-day indeed a great factor in the production of zinc, not because of any new discovery at all, but because processes have been developed within the last three or four years under which refractory ores might be suc-

cessfully treated. As has been suggested here this evening, the world's wealth in agriculture under wise husbandry has experienced no diminution, but the world is suffering constant exhaustion with respect to its mineral wealth. I am advised that the great steel companies are making provision against the day of a dearth of iron ore in this country by securing large deposits in Chile and Cuba. In my opinion, the prime object of the existence of the Bureau of Mines is the conservation of the lives of the men who toil in the mines. And next to that is the conservation of our mineral wealth by making available to man the deposits which, although known, are unworkable at this time. Might I be pardoned for suggesting that the most intimate kind of relationship ought to be cultivated between the Bureau of Mines and those who are actually engaged in carrying on the business of mining. We may rely upon the ingenuity and the enterprise of the mining engineers to apply known processes and recognized methods to the treatment of ores that will render a profit, but we must rely upon the researches of the Bureau of Mines for the development of new processes. They must find the key that will unlock these locked treasure houses and place their great deposits at the service of mankind. Friends of the Bureau of Mines indulge in the expectation that it will meet every reasonable hope that may be entertained for it under the capable management of Mr. Manning, worthy successor to Dr. Holmes, who was loved, respected, and admired by all who were fortunate enough to know him in life."

Mr. J. E. Callbreath, secretary of the American Mining Congress, spoke of the history of the establishment of the Bureau of Mines, and advocated most generous treatment on the part of the Federal Government.

Secretary Franklin K. Lane said it had been a matter of very great pride to him "to be identified with a department which has in its service men of such large information and ability and such self-sacrifice as some of the chemists and engineers we have in the Bureau of Mines." He mentioned Rittman, Parsons, Moore, Cottrell. "It is a great pleasure for me to stand here and speak with such appreciation of the men who are in this department and who are doing the kind of work that has not been done in the United States before, and as Edison outdid the rest of the world in invention, so we will outdo the rest of the world in chemistry, though we are but babies now."

In verses of Kipling Secretary Lane paid a tribute to the late J. A. Holmes, and concluded:

"Mr. Callbreath spoke of safety first. I rather like the toast of the President, 'America first.' And these two are one and they are linked together in the Bureau of Mines and what it stands for. Safety for ourselves and safety for our country—the pre-eminence of our country. And what is to stop our country from being pre-eminent when we have the men who can find out the secrets of nature, and having reserved more of this foundation material which goes to make a great industrial people of our or any other nation, because we have passed now into an industrial world and war seems to be the chief industry? At least, it is an industry by itself and to-day it is being conducted as an expression of the most intense industrial life. There was a time when a war was just a meeting of a lot of men with swords, and then they sang to the man who made the sword. But the sword plays no part to-day. Down at the bottom it means immense mineral reserves from development and from most intensive use. Barbed wire, mechanics, chauffeurs, railroads, cannon, high explosives, automobiles, everything that a great industrial nation has, constitutes the army now when comes the war, and we are an army pre-eminently great in leading any onslaught, because we have mineral resources greater than those of any other country.

"We can build a battleship out of the mines of the United States, and no other country can make that boast. And it is the plan to make the Bureau of Mines a great conservation institution, saving from waste, putting in use; and I have no doubt but that the President was wise, as wise as usual, when he selected to direct the work of that bureau, Mr. Manning."

Mr. Van H. Manning replied in part as follows:

"There has been more or less discussion as to who is responsible for the propaganda of 'Safety First.' The Bureau of Mines has never claimed responsibility for the safety-first movement in the mines, but it has very properly claimed the responsibility for the national movement. . . .

"I wish it were possible for me to speak to you from the fullness of my heart, but this is impossible. The inspiration of this scene, surrounded as I am by friends, old and new, rejoicing with me, is a strong incentive to a renewed courage in the performance of my duties as Director of the Bureau of Mines. The Director of the Bureau of Mines has been entertained from the Atlantic to the Pacific Coast, from the Great Lake on the North to the Mexican boundary line. These entertainments were given in honor of the officer, but to-night it is the man that you honor by your presence.

"One of the mottoes which I have followed through life has been said: 'He who does the best his circumstance allows, does well, acts nobly. Angels could do no more.' I have been commended for the loyalty I have always maintained to those to whom I am responsible for my work. I would have it said of me: 'His loyalty is e'er the same, whether it is to lose or win the game.' I have been on both sides of the game, having won and lost through my loyalty to a cause I felt to be just.

"I want your friendship among the material things of life, and to make my administration successful I must retain it. I am grateful to the President of the United States for my appointment as Director of the Bureau of Mines; grateful to the Secretary of the Interior, who has assumed great responsibility in my appointment, and grateful to you for the confidence you have expressed in me to-night by assembling here to do me honor.

"When the day is done, I will be satisfied if it is said of me: 'Living he did gain men's good opinions; and now dead leaves his work to the care of noble friends.' "

Obituary

Charles H. Kiessig died at his home in New York City at the age of 65 years. He was born in Leipzig, Saxony, and came to the United States in 1879 to establish the manufacture of ultramarine blue. For the last twenty years he conducted a business as importers' agent. He was well known and universally liked in chemical and paint circles, but his friends in the chemical fields will probably best remember him for the unforgotten smokers on Saturday nights in the old Chemists' Club in Fifty-fifth Street, which he arranged in his quiet, genial manner while chairman of the house committee of the Chemists' Club for several years.

Book Reviews

Mechanical Drawing for Colleges and Universities. By **James D. Phillips** and **Herbert D. Orth.** 284 pages, 295 illustrations. Price, $1.75. New York and Chicago: Scott, Foresman & Co.

A similar book for high schools is to be issued by the same authors, the two books to constitute a complete course. This work, however, seems fairly complete in itself; it lays out a graded course very suitable for college students, with the many practical points and details carefully worked out. The two books together should find a wide use, where the high school can be induced to co-operate to that extent with the college or university. The publishers announce that this is one of their vocational series intended for use in the vocational courses that are now becoming so large a part of public education. Prof. F. D. Crawshaw, of the University of Wisconsin, is editor of the series.

Laboratory Work for Coal Mining Students. By **J. Sim** and **A. M. Wylie.** 4¾ x 7¼ in., 136 pages, 17 cuts. Price, 90 cents. London: Edward Arnold.

A useful little book, well adapted to its purpose. The five chapters concern coal analysis, washing and coking tests of coal, testing of oils, gas analysis and fan tests. While the contents appear well written and useful to coal miners, yet methods of testing the average velocity of air in a gallery or shaft and the ignition point of various mixtures of coal gas and air would appear to be subjects that should not have been omitted, even in a most elementary course.

TN
1
C45
v.13

Chemical engineering

Engin.

ENGIN STORAGE

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY